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AN INVESTIGATION OF THE STABILITY
OF THE COST PERFORMANCE INDEX

THESIS

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AFIT/GCA/LSY/90S-6

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AN INVESTIGATION OF THE STABILITY OF THE COST PERFORMANCE INDEX

THESIS

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Master of Science in Cost Analysis

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Preface

The purpose of this study was to determine if the Cost Performance Index (CPI) was stable for completed aircraft procurement programs managed at Aeronautical Systems Division (AFSC). In demonstrating that the CPI is stable for this group of programs, I am hopeful that this thesis will encourage additional research into CPI stability for other types of programs within the Air Force and within the other services.

I would like to thank my faculty advisor, Captain David S. Christensen, for the valuable guidance, assistance, and support he provided. I would also like to acknowledge Lt Col Thomas L. Bowman who provided the initial idea for this study and was the source of continual support. Finally, I wish to thank my wife, Peggy, and children; Joseph, Michael, and Deanna; who provided unending encouragement and who were always understanding while I wrote this thesis.

Table of Contents

Page

List of Figures

List of Tables

Abstract

This study examines the stability of the Cost Performance Index (CPI). The CPI is an indicator of the cost performance efficiency achieved on a contract and is used to analyze cost performance on defense contracts. It has long been asserted that the index does not change by more than 10 percent after a contract is 50 percent complete, but an exhaustive literature search did not locate any empirical work that supports this assertion. Knowing that the CPI is stable is important because it indicates that a contractor has a healthy management system, it increases the reliability we place in the contractor's planning process, it gives us confidence in our Estimate at Completion computations, and if a contractor is overrunning his budget, it gives us confidence when we declare the contractor in trouble.

After defining CPI stability two methods to test for stability were developed. The two methods chosen were: first, to measure the range of the CPIs that occurred at greater than 50 percent complete and second, to calculate a percentage interval and verify that the CPI falls within the bounds of this interval. The results of both methods show that the CPI is stable after a contract is 50 percent complete.

AN INVESTIGATION OF THE STABILITY OF THE COST PERFORMANCE INDEX

I. Introduction

General Issue

The Cost Performance Index (CPI)[1] has been relied upon as a key indicator for use in the analysis of Cost Performance Report (CPR) data based on the assertion that the CPI is stable (2:1). The assertion that the CPI is stable over time was founded upon a study reported to have been accomplished by the General Accounting Office (GAO). The GAO study was said to have been accomplished in the mid-1970's. One of its "conclusions was that once a contract was 50% complete, its CPI would not change more than +/- .10" (2:1).

This study has found that a stable CPI is important for several reasons. A stable CPI indicates that a contractor has a healthy management system (15), it increases the reliability we place in the contractor's planning process (6), it gives us confidence in our Estimate at Completion computations, and if a contractor is overrunning his budget, it gives us confidence when we declare the contractor in trouble (1).

In conducting the research for this project the GAO study could not be located. One expert in the CPR analysis field doubts that it ever existed (3). Given the uncertainty regarding the GAO study and the importance of a stable CPI, this study investigates CPI stability.

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[1] The CPI is an indicator of the cost performance efficiency achieved on a contract. The CPI will be further defined in Chapter II.

Background

The Cost Performance Index is one of several indicators used in the evaluation of a contractor's performance. The CPI is calculated from data that the contractor reports in the monthly Cost Performance Report. Department of Defense (DoD) Instruction 7000.10 requires that a CPR be submitted for "all contracts which require compliance with the Cost/Schedule Control Systems Criteria (C/SCSC)" (9:2), except firm fixed-price contracts (9:2). Even though the Instruction does not require it, some firm fixed-price contracts also submit CPRs.

The C/SCSC "is a set of criteria designed to define an adequate contractor cost and schedule management control system" (7:v). C/SCSC is not a management system that the Government mandates that the contractor use. The criteria do however, provide guidance on the characteristics of the system the contractor does implement. The criteria have two objectives which are:

> For contractors to use effective internal cost and schedule management control systems, and
>
> For the Government to be able to rely on timely and auditable data produced by those systems for determining product-oriented contract status. (7:v)

The primary data that the Government receives to evaluate the product-oriented contract status mentioned above are contained in the CPR. The CPR "is prepared by [the] contractors and consists of five formats containing cost and related data for measuring contractors' cost and schedule performance" (9:Encl 2,1). The five formats contain the following information:

> Format 1 provides data to measure cost and schedule performance by summary level work breakdown structure elements.

Format 2 provides a similar measurement by organizational or functional cost categories.

Format 3 provides the budget baseline plan against which performance is measured.

Format 4 provides manpower loading forecasts for correlation with the budget plan and cost estimate predictions.

Format 5 is a narrative report used to explain significant cost and schedule variances and other identified contract problems. (9:Encl 2,1-2)

Formats 1 and 2 of the CPR contain the basic data elements used in the evaluation of the contractor's performance. These data elements are:

Actual Cost of Work Performed [ACWP]. The costs actually incurred and recorded in accomplishing the work performed within a given time period.

Budgeted Cost for Work Performed [BCWP]. The sum of the budgets for completed work packages and completed portions of open work packages, plus the applicable portion of the budgets for level of effort and apportioned effort.

Budgeted Cost for Work Scheduled [BCWS]. The sum of the budgets for all work packages, planning packages, etc., scheduled to be accomplished (including in-process work packages), plus the amount of level of effort and apportioned effort scheduled to be accomplished within a given time period.

Contract Budget Base [CBB]. The negotiated contract cost plus the estimated cost of authorized unpriced work.

[Budget at Completion (BAC). CBB less management reserve].

Estimate at Completion [EAC]. Actual direct costs, plus indirect costs allocable to the contract, plus the estimate of costs (direct and indirect) for authorized work remaining.

Management Reserve [MR]. (Synonymous with Management Reserve Budget.) An amount of the total allocated budget withheld for management control purposes rather than designated for the accomplishment of a specific task or set of tasks. It is not a part of the Performance Measurement Baseline. (7:2-1 to 2-2)

Research Problem

The objective of this research is to determine if the CPI is stable The specific hypothesis to be tested is: once a contract is 50 percent or more complete, is the CPI stable?

Investigative Questions. The following investigative questions will be answered.

1. Why is stability of the CPI important?
2. How is percent complete defined?
3. How should stability be defined?
4. How can stability of the CPI be tested?
5. Is the CPI stable?

Investigative questions one, two, and three will be answered by reviewing the applicable literature and by conducting personal and telephone interviews. Question four and five will be answered following identification of an appropriate data base and collection of the data.

Limitations and Assumptions

Due to constraints imposed on data collection, the database used in this study is comprised of aircraft programs managed at Aeronautical Systems Division (Air Force Systems Command). This limited database means that the results of this study are applicable only to Air Force aircraft programs and limits our ability to make inferences about the stability of the CPI in other types of programs or even aircraft programs of the other services.

Our ability to make inferences is also limited by the way percent complete is calculated in this study. To properly test the hypothesis it was necessary to calculate a consistent percent complete by using the

final BAC rather than the monthly BAC. The methodology used for the calculation of percent complete and the rationale for its use are discussed in Chapter III. The effect of using this methodology is that the results of this study can only be inferred to those contracts which are expected to be relatively stable; that is, contracts which are not expected to have significant new effort added.

The following chapters will discuss the current literature as it relates to the CPI, the methodology that this research will follow, the results of the data analysis, and conclusions that can be drawn from this research.

II. Literature Review

CPR Analysis

The CPI is used in the analysis of a contractor's CPR. As stated previously a CPR is required on all contracts which require compliance with the C/SCSC. Using the data contained in the CPR, analysis of the contractor's cost and schedule performance is accomplished. Analysis takes place at all levels within the Department of Defense (DoD), from the Office of the Under Secretary of Defense (Acquisition) to an individual System Program Office (SPO) at one of Air Force Systems Command (AFSC) product divisions. A brief discussion of CPR analysis will be beneficial in understanding the importance of a stable CPI.

CPR Analysis Defined. CPR analysis begins with the examination of the data presented in the CPR. The analyst approaches CPR analysis with three objectives in mind (6; 15). The first objective is to "look for and identify trends, and to highlight areas that are going well and areas that are not going well" (15). When negative trends are identified, they form the basis for searches of additional information from additional sources (15). The second objective is to evaluate the contractor's progress against his plan. The contractor assigns budgets to his scheduled contractual effort and "a time-phased plan [is established] against which actual performance can be compared" (7:3-9). The contractor reports this plan in the CPR and the analyst uses it to evaluate the contractor's progress. The last objective is to use "the information provided in the CPR to make projections of where the contract will ultimately end, or what the likely cost outcome of a

contract will be" (6). CPR analysis, then, is the use of various techniques to examine CPR data to look for and identify trends, to measure the contractor's progress against his plan, and to make forecasts.

Benefits of CPR Analysis. The analysis of CPR data provides managers within DOD several benefits. First, it provides insight into the contractor's "internal management system" (11:27), that is, his "internal cost and schedule management control system" (7:v). The contractor uses his validated (in accordance with AFSCP 173-5) internal management system to produce the CPR. Performing monthly CPR analysis helps the analyst verify that the contractor's validated system is still functioning properly. When the system is functioning properly the analyst has confidence in the validity of the CPR data and in the validity of his analysis.

Analysis also allows the manager to determine the contractor's progress against his plan. It gives the manager a factual basis to estimate the contractor's final performance, and allows him to predict future contract costs (11:27; 16:22; 17:66). Another important use for analysis is its ability to identify potential problem areas in sufficient time to allow the manager to apply corrective action (10:5; 12:17; 13:21; 15; 16:22; 18). A problem might not be solvable, but analysis can "forewarn management of schedule slips and potential cost overruns in time enough that some corrective action can be initiated to curb those trends we see" (18).

Users of CPR Analysis. Decision makers at all levels within the Department of Defense require CPR analysis (14:12). From the Secretary of Defense down to an individual decision maker in a program office,

anyone can, and does, use CPR analysis to monitor contractor performance and identify potential problems.

Tools used in CPR Analysis. Format 1 of the CPR contains the basic data elements used in CPR analysis. These data elements are: ACWP, BCWP, BCWS, BAC, EAC, MR (see definitions in Chapter I). From these data elements the analyst can mathematically calculate several indicators.

Air Force Systems Command Pamphlet (AFSCP) 173-4 lists and describes eight indicators for use in analyzing CPRs, and the list is not exhaustive (8:12-15). Three of the indicators of importance to this study are: the Cost Performance Index (CPI), the To Complete Performance Index (TCPI), and the Schedule Performance Index (SPI).

The CPI[2] is calculated as follows:

$$CPI = BCWP / ACWP \quad (1)$$

It "is an indication of the cost efficiency with which work has been accomplished" (8:13). If, for example, BCWP = $78,875 and ACWP = $91,522, then the CPI = 78,857 / 91,522 = .862. The .862 means that for each dollar the contractor spent on the contract, he received approximately 86 cents worth of value. In this example the CPI is less than 1.0 which indicates that the contractor is experiencing a cost overrun. A CPI of 1.0 indicates that the contractor is on target while a CPI greater than 1.0 indicates a cost underrun (8:14).

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[2] The CPI that is used in this study is the CPI_e. Its inverse, CPI_p = ACWP / BCWP , is occasionally referenced in the literature. The CPI_e, however, is more widely used and referenced.

The TCPI is calculated as follows:

$$TCPI = (BAC - BCWP) / (BAC - ACWP) \qquad (2)$$

The TCPI is used to show what the CPI would have to be for the remainder of the contract in order not to experience a cost overrun or cost underrun. Using the example above and with BAC = $200,000, the TCPI = (200,000 - 78,875) / (200,000 - 91,522) = 1.12. This means that from this time forward to the end of the contract, the contractor's CPI must equal 1.12 or better or the contract will experience a cost overrun (8:14).

The SPI is calculated as follows:

$$SPI = BCWP / BCWS \qquad (3)$$

It "is an indication of the schedule efficiency with which work has been accomplished" (8:14). If, for example BCWP = $78,875 and BCWS = $86,733, then the SPI = 78,875 / 86733 = .909. This means that of the work the contractor was scheduled to have completed to date, about 91 percent of that work has actually been completed. In this example the SPI is less than 1.0 which indicates that the contractor is behind schedule. A SPI of 1.0 indicates that the contractor is on schedule, while a SPI greater than 1.0 indicates that the contractor is ahead of schedule (8:14).

Importance of a Stable CPI

There are several areas where a stable CPI plays an important role in the analysis of contractor data. First, the CPI can be used to indicate the health of the contractor's management system. In this role

the CPI provides evidence that the contractor is or is not using his management system effectively. A stable CPI provides "evidence that [the contractor's] planning, scheduling, estimating, budgeting, and accounting systems are still all working together" (15). An unstable CPI would indicate that the contractor is not using his system in accordance with the contract specifications.

The CPI also, "accurately reflects how well the contractor is performing against his plan. . . . It indicates right away if he is underestimated in his planning or if he is running into gross problems. [If these two situations occur] it normally shows up in additional costs [which are reflected in the CPI]" (18). Stability in the CPI increases the confidence that the program manager can place in the contractor's planning process (6).

"One of the most important capabilities of [CPR] analysis is the use of formulas to project the final cost of a contract" (10:1-2). The CPI is heavily weighted in several of the formulas that generate these projections of final cost, or Estimates at Completion (EAC). The formula preferred by HQ Air Force Systems Command uses an .80/.20 weighting of the CPI and Schedule Performance Index (SPI) respectively. The preferred HQ air Force Systems Command formula is:

$$EAC = ACWP + (BAC - BCWP) / (.2\ SPI + .8\ CPI) \qquad (4)$$

where ACWP and BCWP are both cumulative to date values. One expert says the CPI is used in this and other EAC formulas based on the assertion of stability made in the unlocated GAO study. This assertion is one reason "we rely so heavily on the CPI in our EAC forecasts" (2:1).

A stable CPI also gives us confidence in declaring a contractor in trouble when we see him overrunning his budget. According to an OSD analyst "when a contract is 15% to 20% complete [and a contractor is in trouble] you are not going to [see him] do better later on in the latter stages of the contract" (1).

> [The C/SCSC discipline] requires that the [contractor's] budget be spread out over the life of the contract, in the near term it will be in some level of detail, [and] in the far term it's going to be in some higher level of detail. Then [if] you overrun that near term work, given the nature of the budgeting systems, do you have any reasonable expectation that later on when you get into the harder stuff, when the work gets tougher and less well defined, and there's [less] budget remaining when you get to the end [of a project than] there was at the beginning, what makes one think that they're going to underrun what they've previously been overrunning? It just doesn't happen. (1)

This idea can be demonstrated in an example using the TCPI and the CPI. If the TCPI is 1.10 your CPI must be equal or near to 1.10 for the remainder of the contract to meet your budget. If the CPI is determined to be stable and the contractor's CPI is currently at the .90 level, then we can be confident that the contractor will overrun the contract because he will never be able to reach the 1.10 level (5).

Percent Complete

Percent complete is "an estimate or mathematical calculation of the percent of a . . . [contract] that has been physically accomplished" (4:10). It is calculated as follows:

$$\text{PERCENT COMPLETE} = \text{BCWP} / \text{BAC} \tag{5}$$

Percent complete is the ratio of the amount of work that has been accomplished to date to the total amount of work that is to be accomplished. The denominator usually used in calculating percent

complete is the BAC. However, if MR is expected to be used on the contract, then the CBB or the BAC plus any portion of the MR that is expected to be used, may be substituted for BAC (8:12). In addition to using the BAC, CBB, or the BAC plus some portion of the MR, in some cases the EAC is also used to compute percent complete. The specific method used to calculate percent complete in this project will be discussed in the following chapter.

CPI Stability Defined

Managers have used the CPI as a key indicator because of its asserted stability. The assertion of stability came from reports that the GAO had accomplished a study that had found the CPI to be stable. This alleged study reportedly defined a stable CPI as one which would not vary more than plus or minus 10 percent once the contract was more than 50 percent complete (2:1). Since managers have relied on this definition for a stable CPI, this study will use the same definition.

The discussion above has answered the first three investigative questions that were posed in Chapter I. The questions answered are: why is stability of the CPI important, how is percent complete defined, and how should stability be defined? The next chapter will present the methodology that will be used to test the hypothesis, which is: once a contract is 50 percent or more complete, is the CPI stable?

III. Methodology

The Database

The database used in this study was obtained from the Aeronautical Systems Division's (ASD) Cost Library. The database consists of cost performance data from 26 CPRs for seven aircraft procurement programs. The data were collected from the monthly CPRs and include BCWS, BCWP, ACWP, BAC, and date (month and year of the CPR). All data elements were taken from the total line of the CPR. Because some of the data are proprietary the data are not included in this study. The data are available from ASD/ACCR (the ASD Cost Library) or ASD/ACCM Wright-Patterson AFB OH 45433.

Due to the lack of travel funds and time constraints imposed on the data collection activity, the database was restricted to seven aircraft programs. Lack of travel funds eliminated the possibility for travel to other Air Force System Command product divisions, so only data available at ASD was included in the database. In addition, time constraints did not permit all of the data available in the ASD Cost Library to be included in the database. After consultation with senior management within the cost performance discipline at ASD, it was determined that aircraft programs would be the most appropriate for the test of the research hypothesis. Aircraft programs were selected over other types of programs because the management felt that the primary mission of ASD is the procurement of aircraft systems. Therefore, if the study had to be limited, the management felt that aircraft programs should be the ones included in the study.

To properly test the research hypothesis the programs included in the database had to be completed. The definition of complete used in this research is: the program has a CPR noted as the final CPR, or the program is greater than 95 percent complete, or the final aircraft has been delivered. Only the seven aircraft programs included in the database met this definition.

Aircraft Programs Used. The database consists of cost performance data for seven aircraft procurement programs. Five of these seven programs were structured to included more than one series of CPRs. The different series of CPRs were needed to capture cost performance data during different phases of the aircraft program. For example, if the program had a separate development phase, there was a separate CPR series for that phase. Usually, there was also a separate CPR series for each fiscal year aircraft buy. Table 9, Appendix A, lists the seven aircraft programs included in the database and the CPR series that make up those programs. The table also includes the dates of the initial CPR and final CPR for each CPR series included in the database. The period of performance for these programs ranges from December 1966 to March 1989. Changes in CPR reporting and changes in contracting philosophy are evident in the CPRs covering these 22 years. Specific differences between programs due to CPR reporting are discussed below. Changes in contracting philosophy can be shown by the structure of CPR reporting. Some programs like the A-10 have a separate CPR series for each lot while the B-1B has one CPR series for the entire program.

This difference in reporting structure created a problem in calculating the percent complete for a program. When a program was structured by lot and there was a separate CPR series for each lot, the

monthly percent complete (cumulative BCWP divided by BAC) progressed at an even rate over time. This was because BAC did not change significantly over the life of the lot. Programs with only one CPR series, however, did not exhibit this behavior. In these programs the BAC would change dramatically when additional aircraft were added to the contract. Percent complete in the B-1B Production Program dropped from 67 percent complete to 48 percent complete in one month, with the addition of new effort. This change in percent complete can occur even though the amount of work performed and the cost of that work have increased only slightly.

To test the stated hypothesis the CPI must be associated with a consistent percent complete. When percent complete is allowed to vary to these extremes, this consistency is destroyed. To prevent these variations it was decided to use the final BAC from each CPR series to calculate percent complete. When the final BAC is used in the calculation, percent complete represents the amount of the total contract that has been completed. If the monthly BAC had been used it would represent the amount of current contract effort that has been completed. In this research percent complete is calculated by dividing cumulative BCWP by the final BAC.

CPR Reporting

The greatest difficulty in collecting the data came from the difference in CPR reporting among the various programs. During the 22 years spanned by these program the terminology used and the structure of the CPR have changed significantly. These differences made it particularly difficult to collect a consistently defined BAC across all

the aircraft programs. The BAC that was used for each program is defined below.

A-10 All Lots. The total of the At Completion - Budgeted column was used. This includes Undistributed Budget and Management Reserve.

B-1B Production. The total of the At Completion - Budgeted column was used. This includes Undistributed Budget and Management Reserve.

C-5A RDT&E and Production. This program used two different CPR formats. The change in formats occurred with the June 1971 report. For the June 1971 and later reports, the total of the At Completion - Total BCWS column was used. This included Management Reserve. For the reports prior to June 1971, the total direct of the At Completion - Latest SPO Estimate column was used. Definitions of the data contained in each column were found in the 30 November 1967 CPR for the F-111. According to these definitions the BAC should have been the sum of Total Direct of the At Completion - Contract as Now Definitized from page 1 of the CPR (column 12) and the Total Direct of the Authorized But Not Definitized as of End of Reporting Period - Scope column from page 3 of the CPR (column 18). However, if this sum had been used, BAC would have been less than BCWP. Therefore, the Latest SPO Estimate was used because it more nearly matched the BAC in the June 1971 and later CPRs.

C-5B Production. The total of the At Completion - Budgeted column was used. This includes Undistributed Budget and Management Reserve.

F-111 RDT&E and Production. This program also used two different CPR formats with the change occurring on the September 1971 CPR. For the September 1971 and later reports, the Subtotal of the At Completion - Latest Estimated Target column was used. For the reports prior to September 1971, the Subtotal of the At Completion - Contract as Now

Definitized column (page 1 column 12) plus the Total Direct of the Authorized But Not Definitized as of End of Reporting Period - Scope column (page 3 column 18) was used.

F-111F Production. The BAC used for this model of the F-111 program is identical to that described above except that the change in reports occurred with the June 1973 report.

F-15 RDT&E and Production. The total of the At Completion - Budgeted column was used. This includes Undistributed Budget and Management Reserve.

F-16 FSED and Production. The total of the At Completion - Budgeted column was used. This includes Undistributed Budget and Management Reserve.

In addition to the difficulties in capturing an accurate value for BAC, the C-5A and the F-15 programs combined the RDT&E and Production phases in the same CPR series. This eliminated the possibility of testing the hypothesis separately for the RDT&E and Productions phases of the programs. Therefore, the database as a whole is used for testing the hypothesis with no stratification. In the remainder of this study the term "contract" will be used to indicate each CPR series that was included in the database.

CPI and Percent Complete Calculations

Following data collection the data were entered into a Quattro Spreadsheet by contract. Using the spreadsheet program the CPI was calculated using the monthly cumulative to date BCWP and the monthly cumulative to date ACWP and percent complete was calculated using the monthly cumulative to date BCWP and the final BAC. Finally graphs of

these two variables were generated for each contract. The graphs display percent complete on the x axis, CPI on the y axis and are included in Appendix B. Using these graphs, two methods to test the hypothesis were chosen.

Hypothesis Tests

The hypothesis that is to be tested is: once a contract is 50 percent or more complete, is the CPI stable? The two methods chosen to test this hypothesis are: first, to measure the range of the CPIs that occurred at greater than 50 percent complete and second, to calculate a percentage interval and verify that the CPI falls within the bounds of this interval. In both of these methods we are examining the CPIs that occur after some stated percent complete. In this study when an initial percent complete is given it refers to all those CPIs that lie between the initial percent complete and the end of the contract. When a specific CPI is referred to, such as the CPI at 50 percent complete, this means the first CPI that occurs after the contract is 50 percent or greater complete.

The Range Method. In the first method (the range method) the CPI range is computed for each contract. The range is calculated by selecting only the CPIs that occur after the program is greater than 50 percent complete and determining the minimum and maximum CPIs. The difference between these two CPIs is the range.

This method measures stability of the CPI by examining the magnitude of the range. If, for a given contract, the range is small, there would be little variation between the minimum and maximum CPIs and we would conclude that the CPI is stable. On the other hand, if the

range were large, there would be a great deal of variation between the minimum and maximum CPIs and we would conclude that the CPI is unstable.

<u>The Interval Method</u>. The second method (the interval method) chosen to test the hypothesis is to calculate a +/- 10 percent interval. The interval is calculated by taking the CPI that occurs when the contract is 50 percent complete and multiplying it by 10 percent. The result is added to the CPI to obtain the upper bound of the interval and the result is subtracted from the CPI to obtain the lower bound of the interval. This results in an percentage interval that is centered around the CPI. The stability of the CPI is tested by determining if all the CPIs fall within the upper and lower bounds. We can determine if the CPIs for the remainder of the contract fall within the percentage interval by noting if the minimum and maximum CPIs, found in the range method, are between the upper and lower bounds of the percentage interval.

This method measures the stability of the CPI by determining if all the CPIs that occur after the contract is greater than 50 percent complete fall within the percentage interval. If, for a given contract, all the CPIs fall within the percentage interval, we would conclude that the CPI is stable. If, on the other hand, any CPI does not fall within the percentage interval we would conclude that the CPI is not stable.

An advantage of the range method is that the range is not centered on a predetermined CPI (the CPI at 50 percent). In the range method the range is strictly determined by the minimum and maximum CPIs that occur after the contract is greater than 50 percent complete. In the interval method the upper and lower bounds of the percentage interval depends on the value of the CPI at 50 percent complete. If the CPI happens to be a

maximum then the upper half of the percentage interval would be irrelevant. In this case the test would turn out to be a minus 10 percent interval. The reverse would be true if the CPI at 50 percent complete happened to be the minimum CPI. By using the range you measure the actual variation between the maximum and minimum CPI without reference to a specific CPI.

An advantage of the interval method is that if the CPI is found to be stable it duplicates the findings of the unlocated GAO study.

In addition to performing the tests as outlined above, to allow for a sensitivity analysis the tests will also be performed at 40, 30, 20, 10, and 0 percent complete. For the interval method percentage intervals will be calculated for 7.5 percent and 5.0 percent.

Definition of Stability

As stated in Chapter II, a stable CPI will be defined as one which does not vary more than +/- 10 percent once the contract is more than 50 percent complete. This definition works well for the interval method but needs further refinement for use with the range method. Because of the relationship between the range and the percentage used in a percentage interval, in the range method a stable CPI will be defined as one with a range that does not exceed 0.20.

This chapter has discussed the methodology that was used to test the hypothesis that was described in Chapter I. The two methods to be used are the Range Method and the Interval Method. The definition of stability that was introduced in Chapter II was further refined for use with the Range Method. The next chapter will report the results of calculations using these methods.

IV. Results

This chapter presents the results of the calculations described in the previous chapter. The results using the range method will be presented first followed by the results of the interval method.

The Range Method

The range method is the calculation of the range between the maximum and minimum CPI. The range is computed for those CPIs observed between 50 percent complete and the end of the contract. To allow for a sensitivity analysis the range was also computed beginning at 40, 30, 20, 10, and 0 percent complete. The result of these calculations are at Tables 11 through 16 in Appendix C. The tables include the maximum CPI, minimum CPI, and the range for each percent complete. These calculations are summarized below in Table 1. The table includes the initial percent complete, the number of contracts which were stable (the range less than 0.20), the total number of contracts, the percentage of contracts which were stable, the maximum range observed, the minimum range observed, the mean of the ranges, and the standard deviation of the ranges. The total number of contracts will change because in stepping backwards from the initial 50 percent complete starting point, there are some contracts which do not have any observations in the next interval. For example the F-111 RDT&E contracts first CPI occurs at 50 percent complete and has no observations between 0 and 50 percent complete. Therefore it is not included in the 40 percent complete and later tables as a contract.

Table 1

Results of the Range Method

	Initial Percent Complete					
	50%	40%	30%	20%	10%	0%
Stable Contracts	26	25	25	25	24	10
Number of Contracts	26	25	25	25	25	19
Percent	100%	100%	100%	100%	96%	53%
Maximum Range	0.093	0.108	0.123	0.163	0.206	0.719
Minimum Range	0.015	0.015	0.015	0.016	0.030	0.031
Mean Range	0.044	0.052	0.060	0.076	0.092	0.236
Standard Deviation	0.019	0.023	0.027	0.042	0.047	0.152

Figure 1 is a graphical representation of a portion of the data contained in Table 1. For each of the initial percents complete the vertical line represents the difference between the maximum and minimum ranges. The top of the line is located at the value of the maximum range and the bottom of the line is located at the value of the minimum range. The horizontal tic mark on each line is located at the value of the mean range. The term initial percent complete refers to all those CPIs that lie between the stated percent complete and the end of the contract.

The Interval Method

The interval method is the calculation of +/- 10 percent interval for the CPI that occurs at 50 percent complete and then determining if both the maximum and minimum CPI fall within that interval. A sensitivity analysis was allowed for by calculating the percentage interval at 40, 30, 20, 10, and 0 percent complete and also by using 7.5

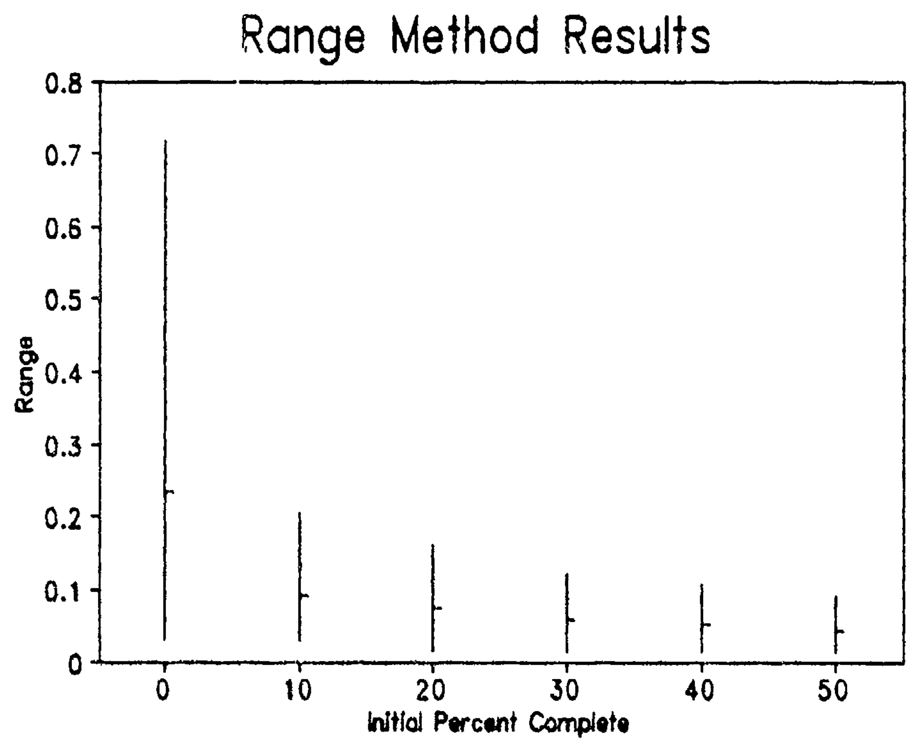

Figure 1. Results of the Range Method

and 5 percent intervals. The results of these calculations are at Tables 17 through 22 in Appendix D. The tables include the values for plus 10 percent, minus 10 percent, plus 7.5 percent, minus 7.5 percent, plus 5 percent, and minus 5 percent for each percent complete. These calculations are summarized below in Tables 2 through 7. There is a separate table for each percent complete which includes the number of contracts which were stable (the maximum and minimum CPIs were within the percentage interval) by percentage interval, the total number of contracts by percentage interval, and the percentage of contracts which

were stable. As in method one the number of total contracts will change.

Table 2

Results of Interval Method for 50 Percent Initial Beginning Point

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	26	25	21
Number of Contracts	26	26	26
Percent Stable	100%	96%	81%

Table 3

Results of Interval Method for 40 Percent Initial Beginning Point

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	24	23	16
Number of Contracts	25	25	25
Percent Stable	96%	92%	64%

Table 4

Results of Interval Method for 30 Percent Initial Beginning Point

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	23	20	14
Number of Contracts	25	25	25
Percent Stable	92%	80%	56%

Table 5

Results of Interval Method for 20 Percent Initial Beginning Point

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	21	17	15
Number of Contracts	25	25	25
Percent Stable	84%	68%	60%

Table 6

Results of Interval Method for 10 Percent Initial Beginning Point

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	17	15	7
Number of Contracts	25	25	25
Percent Stable	68%	60%	28%

Table 7

Results of Interval Method for 0 Percent Initial Beginning Point

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	7	4	3
Number of Contracts	19	19	19
Percent Stable	37%	21%	16%

Analysis of Results

The results from the range method show that the CPI is stable for all contracts from the 50 percent beginning point. The results of the sensitivity analysis show that the CPI is also stable for all contracts from the 40, 30, and 20 percent beginning points and at the 10 percent beginning point the CPI is stable for all but one of the contracts.

The interval method results indicate that the CPI is stable for all the contracts only for a +/- 10 percent interval at the 50 percent beginning point. The sensitivity analysis revealed that all but one contract was stable for a +/- 7.5 percent interval at the 50 percent beginning point and a +/- 10 percent interval at the 40 percent beginning point. The remaining percentage intervals had more than one non-stable contract.

Using the range method, the CPI was stable from the 20 percent beginning point. However, using the interval method, the CPI was stable from the 50 percent beginning point. The difference between these two methods can be attributed to the fact that, as described in the previous chapter, the percentage interval calculated by the interval method is centered on a predetermined CPI. When the CPI that is used to calculate the percentage interval is not exactly centered between the maximum and minimum CPI, a portion of the percentage interval becomes irrelevant. Had the CPI that was used to calculate the percentage interval been centered, the results of the two methods would have been more nearly equal.

The Effect of Using the Current Month BAC

In actual practice the analyst performing CPR analysis does not know what the final BAC will be until the final CPR is received. The analyst, therefore, must make his percent complete computations using the BAC reported in the current CPR. To determine if computing percent complete using the current month BAC would affect the findings of CPI stability presented above, an additional sensitivity analysis was performed. Both the range and the +/- 10, 7.5, and 5 percent percentage intervals were calculated from the 50 percent beginning point where percent complete was calculated using the current month BAC.

The results of the range method calculations, presented in Table 8, are nearly identical to the earlier results. The only difference is that the value of the mean range and the standard deviation have changed. The results of the percentage interval method calculations, presented in Table 9, are also nearly identical. The difference is that 20 of the contracts are now stable where 21 were stable before.

This chapter has presented the results of calculations using the methodology described in the previous chapter. The next chapter will summarize the results of this study and present a conclusion which can be drawn from this research.

Table 8

Results of the Range Method Using Current Month BAC

	Initial Percent Complete
	50%
Stable Contracts	26
Number of Contracts	26
Percent Stable	100%
Maximum Range	0.093
Minimum Range	0.015
Mean Range	0.047
Standard Deviation	0.020

Table 9

Results of Interval Method for 50 Percent Initial Beginning Point Using Current Month BAC

	Percentage Interval		
	10%	7.5%	5%
Stable Contracts	26	25	20
Number of Contracts	26	26	26
Percent Stable	100%	96%	77%

V. Discussion and Conclusion

A Review of the Hypothesis

The research hypothesis that was tested was that the CPI is stable after a report is greater than 50 percent complete. This hypothesis was tested using a database of 26 Cost Performance Reports. Two different tests were applied to this database: first, a test of the range of the CPIs and second, a test of the percentage interval within which the CPIs fell.

Conclusion

Both tests indicated that the CPI was stable after a contract is greater than 50 percent complete. The results of the sensitivity analysis indicated that for the range test the CPI was stable after a contract is greater than 20 percent complete while the percentage interval test showed that the CPI is only stable for after a contract is greater than 50 percent complete and only for a +/- 10 percent interval.

Discussion

The results show that the CPI is stable. As described in Chapter II, one reason that a stable CPI is important is that it gives the manager confidence in declaring a contractor in trouble when we see him overrunning his budget. With a stable CPI we know that when a program reaches 50 percent complete, the CPI will not change by more than 10 percent for the rest of the contract. If the contractor is experiencing an overrun we can compare the CPI with the TCPI (the TCPI tells us what the CPI must be for the remainder of the contract for the

contractor meet the budgetary goal). If there is more than a 10 percent difference between the two, the stable CPI says that the CPI will never equal the TCPI. This means that, in this situation, the manager can be reasonably certain that the contract will not meet the budgetary goal (e.g., overrun). This is true even if the contractor says he will be able to correct whatever problem is causing the overrun.

Another reason for the importance of a stable CPI is the role of the CPI in EAC computations. In the past managers have used the assertion of stability in the unlocated GAO study to heavily weight the CPI in several of their EAC formulas. The finding of stability in this study supports the GAO assertion and allows managers to continue the heavy weighting of the CPI in their EAC calculations.

Recommendation for Further Research

Since the conclusions reached in this research were based on a database that only included USAF aircraft, it is appropriate to question their applicability to US Army and US Navy aircraft or other types of programs such as avionics, engines, missiles, and etcetera. Further research into these other types of programs is recommended.

Appendix A: Aircraft Programs Included in the Study

TABLE 10

Aircraft Programs Included in Study

Contract	Initial CPR	Final CPR
A-10 Program		
FSED	Mar 1973	Aug 1978
Option 1A	Jan 1975	Jul 1977
Option 2A	Sep 1975	Jul 1977
Option 3/4	Jun 1976	Apr 1978
Option 5A	Dec 1976	Apr 1979
Option 6A	Dec 1977	Apr 1980
Option 7A	Jul 1979	Apr 1981
B-1B Program		
Production	Apr 1982	Dec 1989
C-5A Program		
FSED	Feb 1967	Feb 1972
Production	Dec 1966	Feb 1972
C-5B Program		
Production	Oct 1982	Apr 1989
F-111 Program		
RDT&E	Dec 1966	Jul 1973
Production	Nov 1967	Sep 1976
F Model 72-75	Sep 1972	Nov 1975
F Model 74-75	Mar 1974	Feb 1977
F-15 Program		
Thru Wing I	Mar 1970	May 1979
FY 75	Sep 1975	May 1979
FY 76/7T	Sep 1976	Dec 1979
FY 77	May 1977	Mar 1981
FY 78	Aug 1978	Apr 1982
F-16 Program		
FSED	Jan 1975	Jun 1981
FY 80	Dec 1980	Jul 1982
FY 81	Oct 1981	Jul 1983
FY 83	Oct 1983	Apr 1986
FY 84	Nov 1983	Feb 1989
FY 85	Nov 1984	Jan 1989

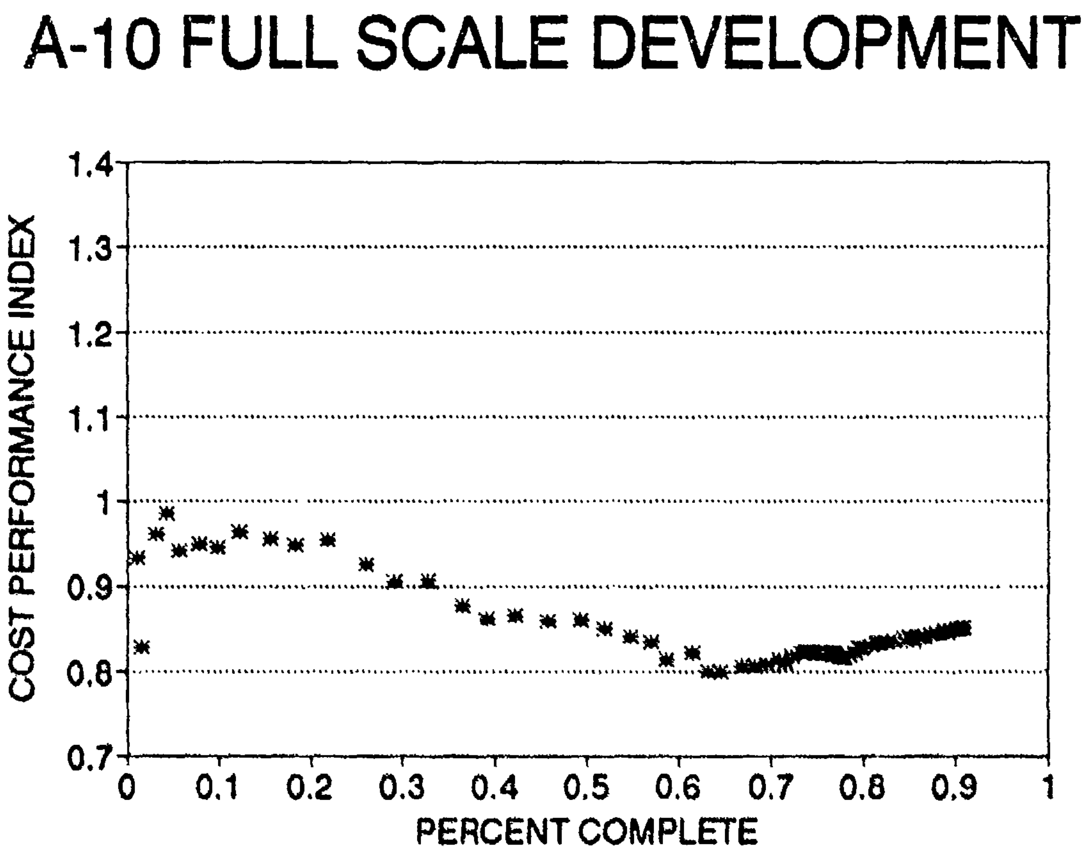

Figure 2. A-10 Full Scale Development

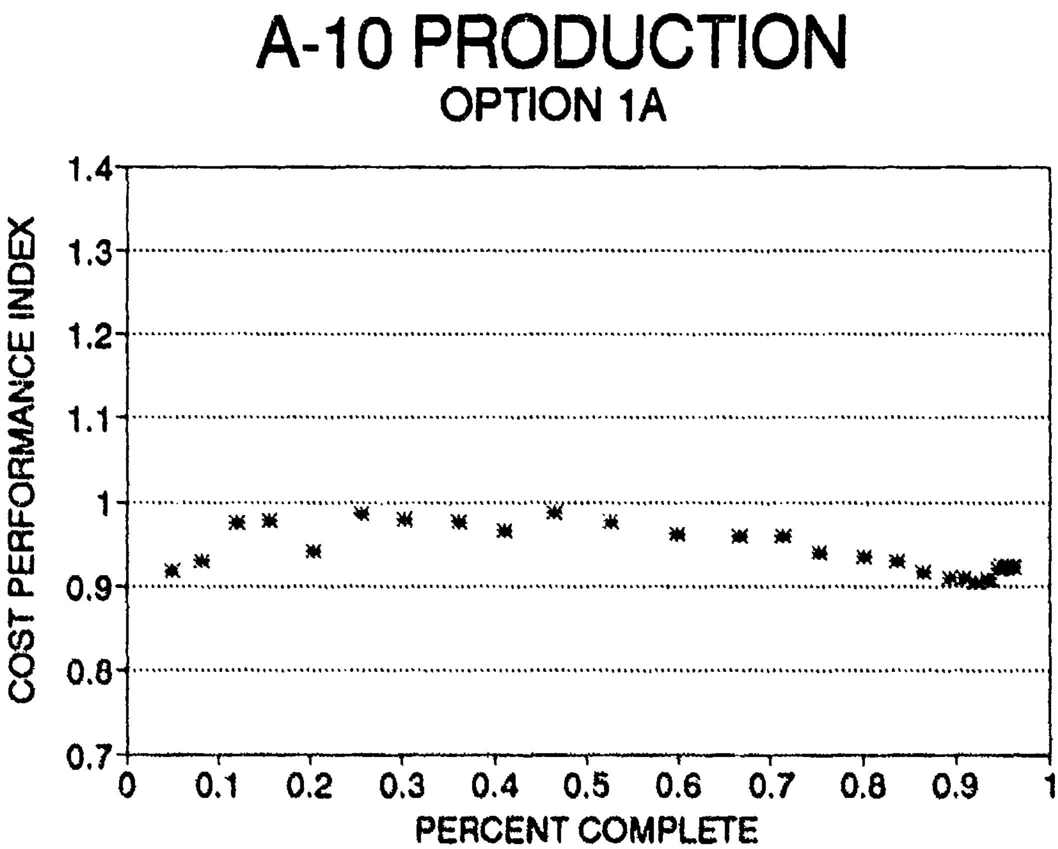

Figure 3. A-10 Production Option 1A

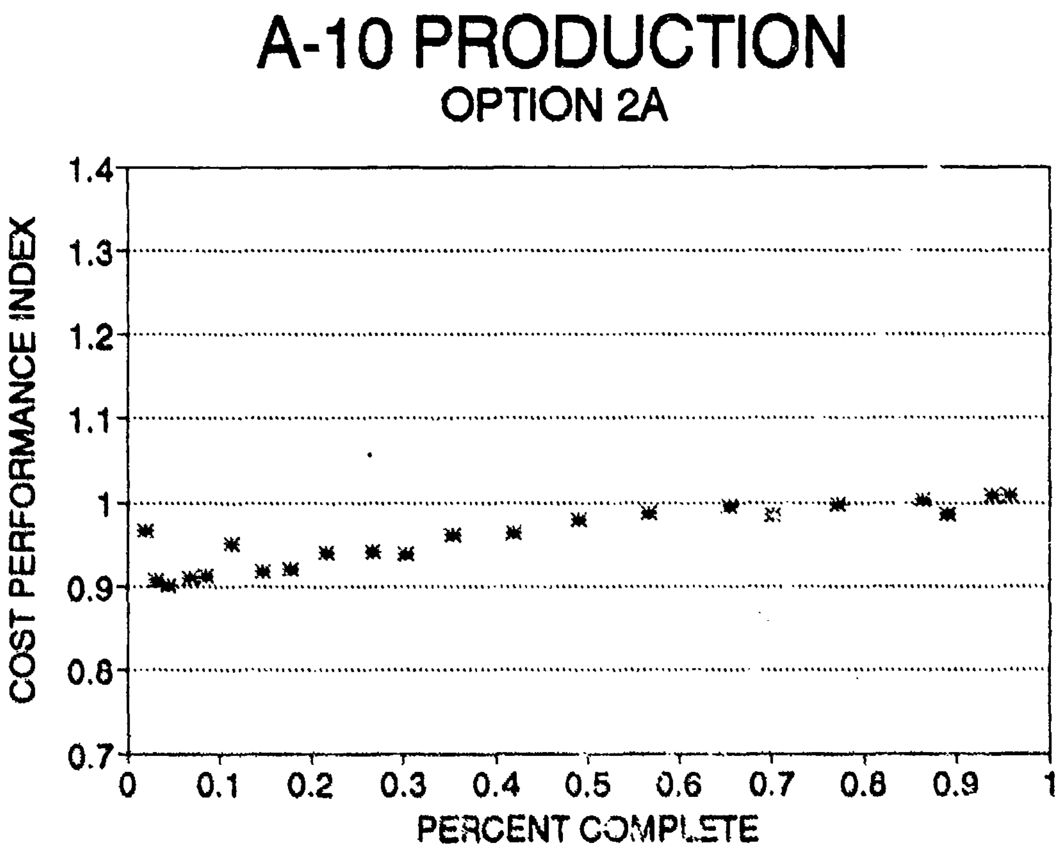

Figure 4. A-10 Produc'ion Option 2A

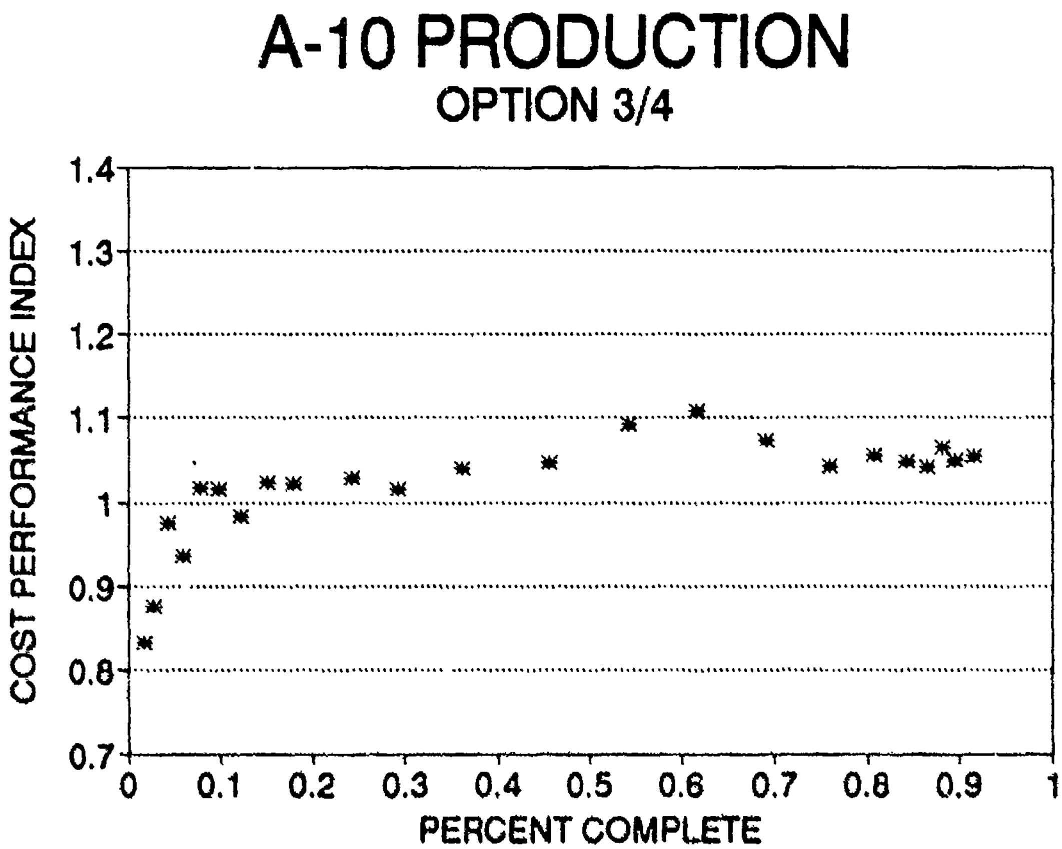

Figure 5. A-10 Production Option 3/4

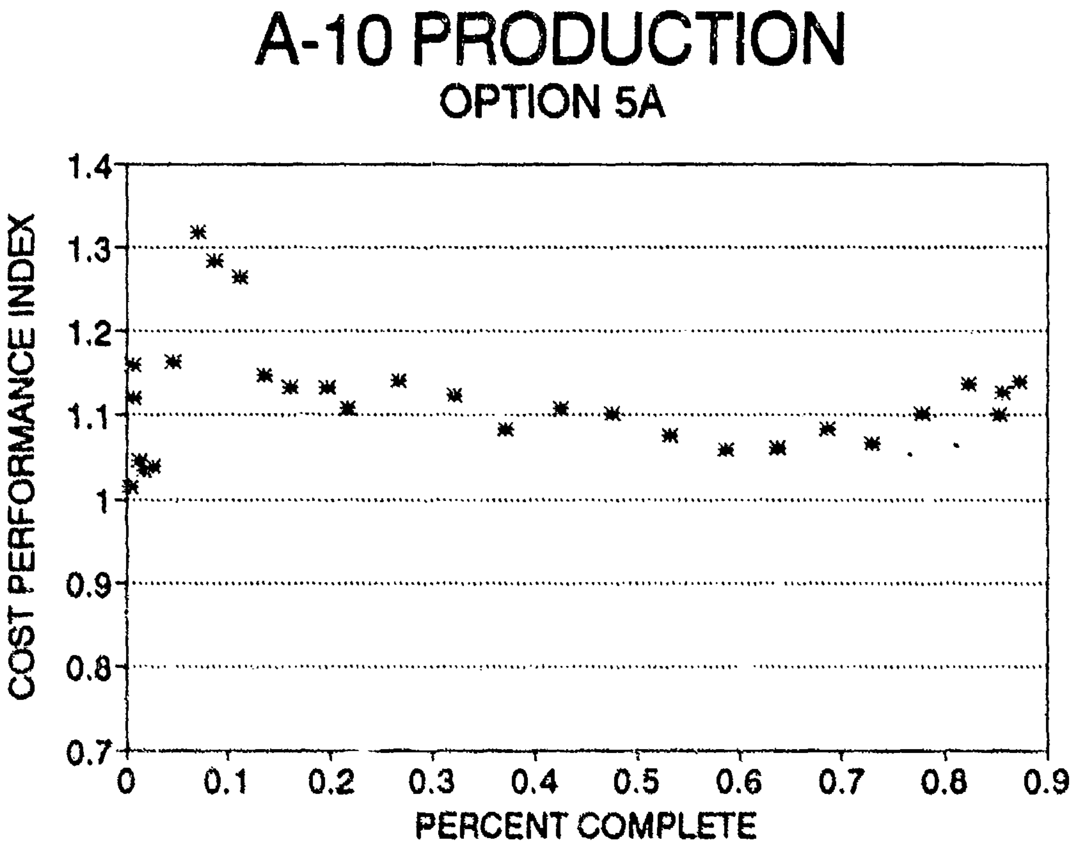

Figure 6. A-10 Production Option 5A

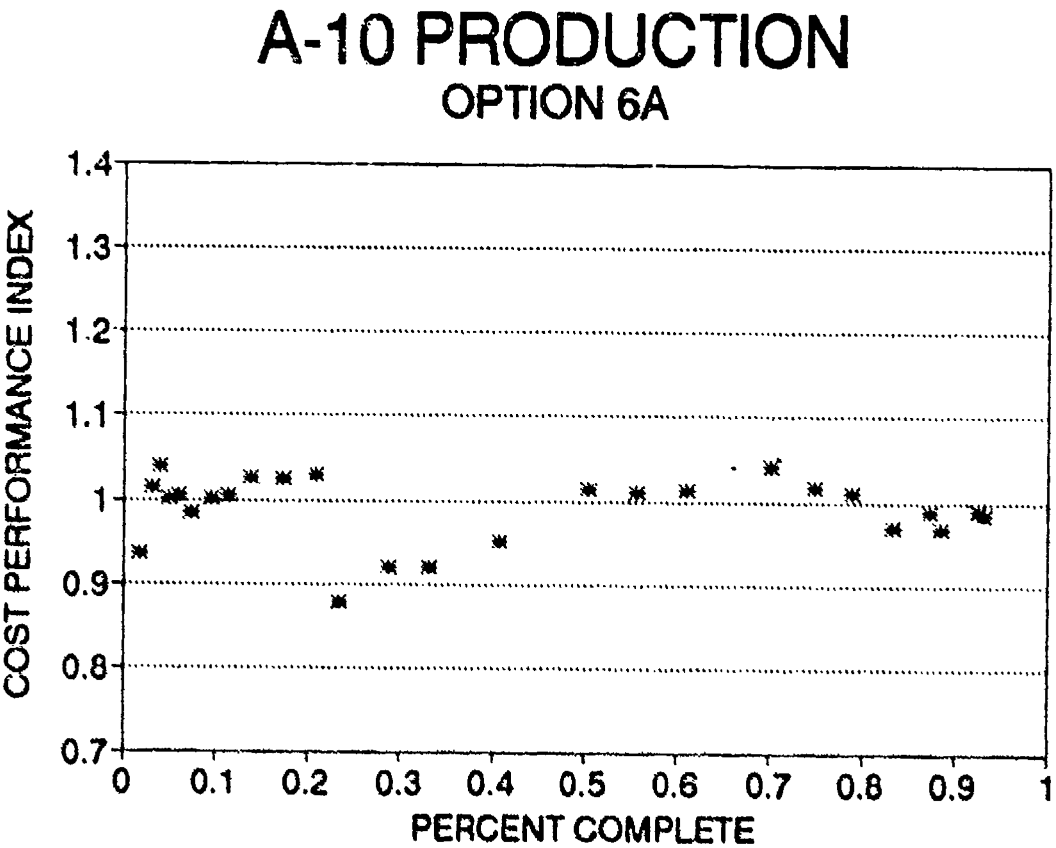

Figure 7. A-10 Production Option 6A

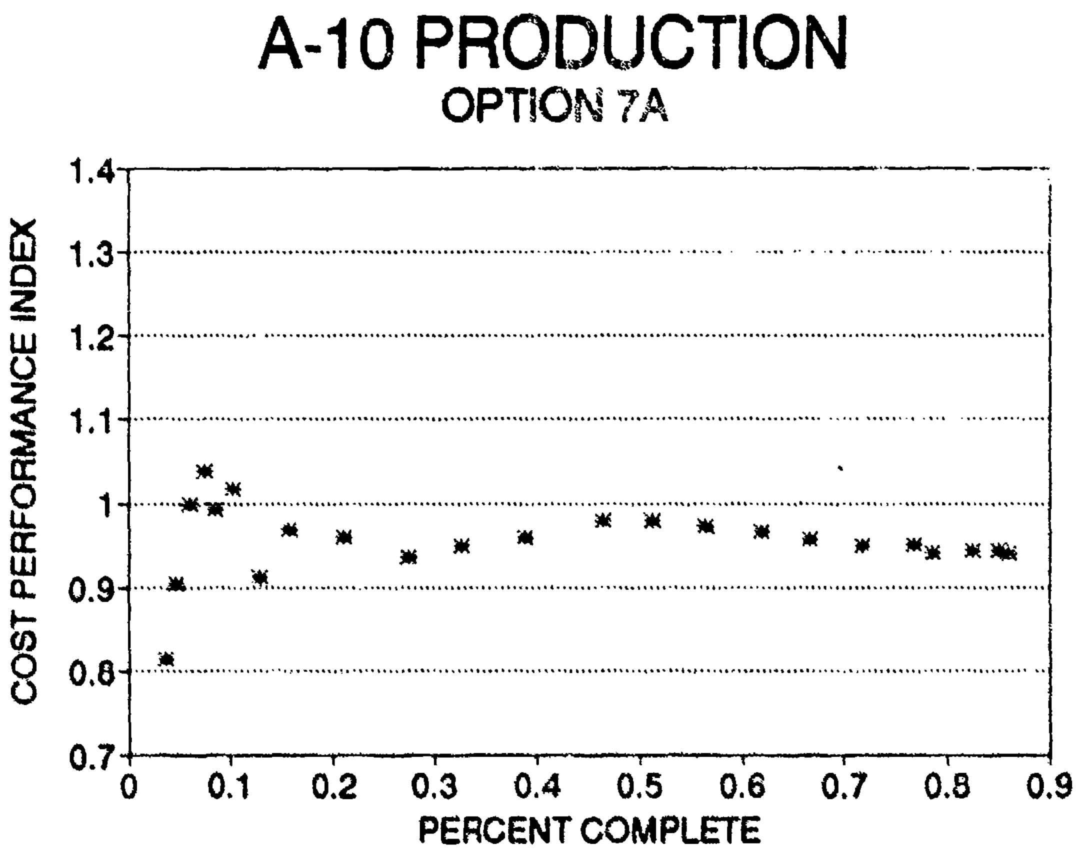

Figure 8. A-10 Production Option 7A

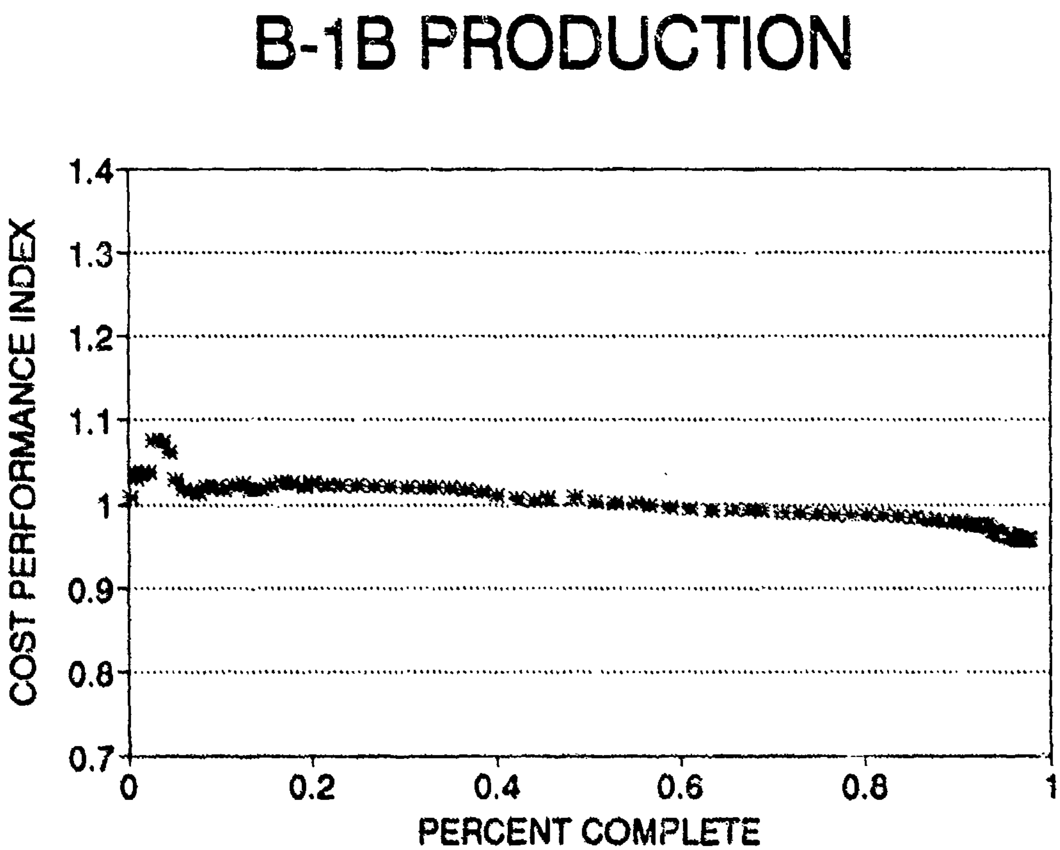

Figure 9. B-1B Production

C-5A FULL SCALE DEVELOPMENT

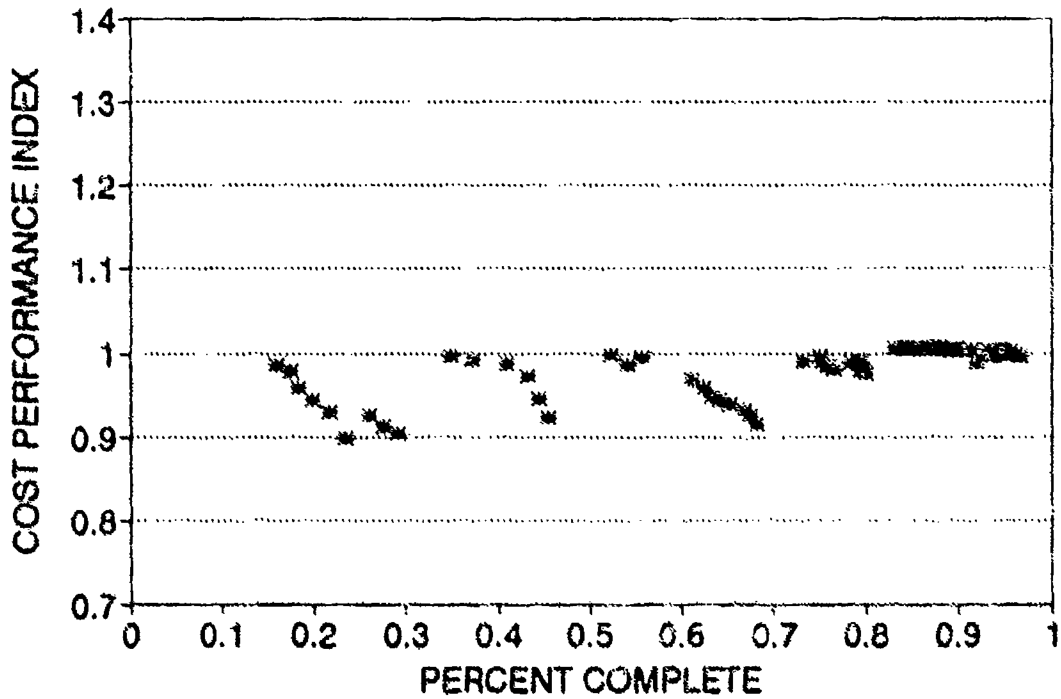

Figure 10. C-5A Full Scale Development

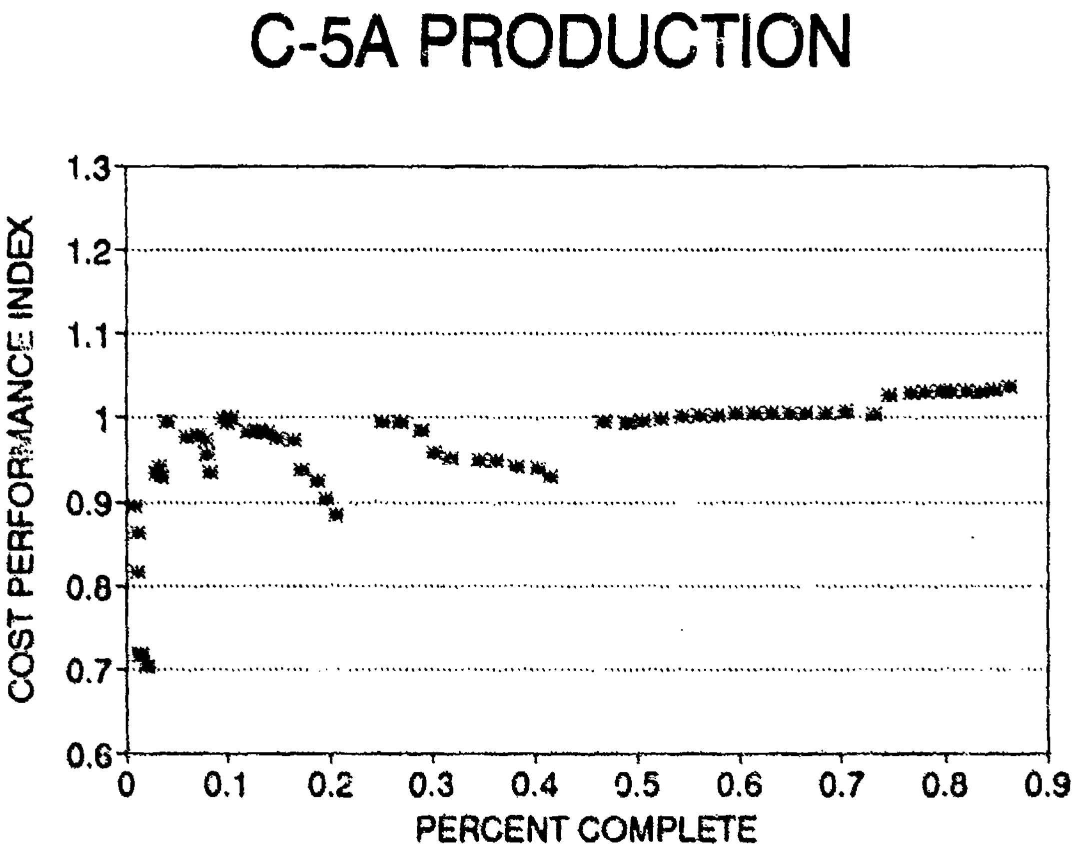

Figure 11. C-5A Production

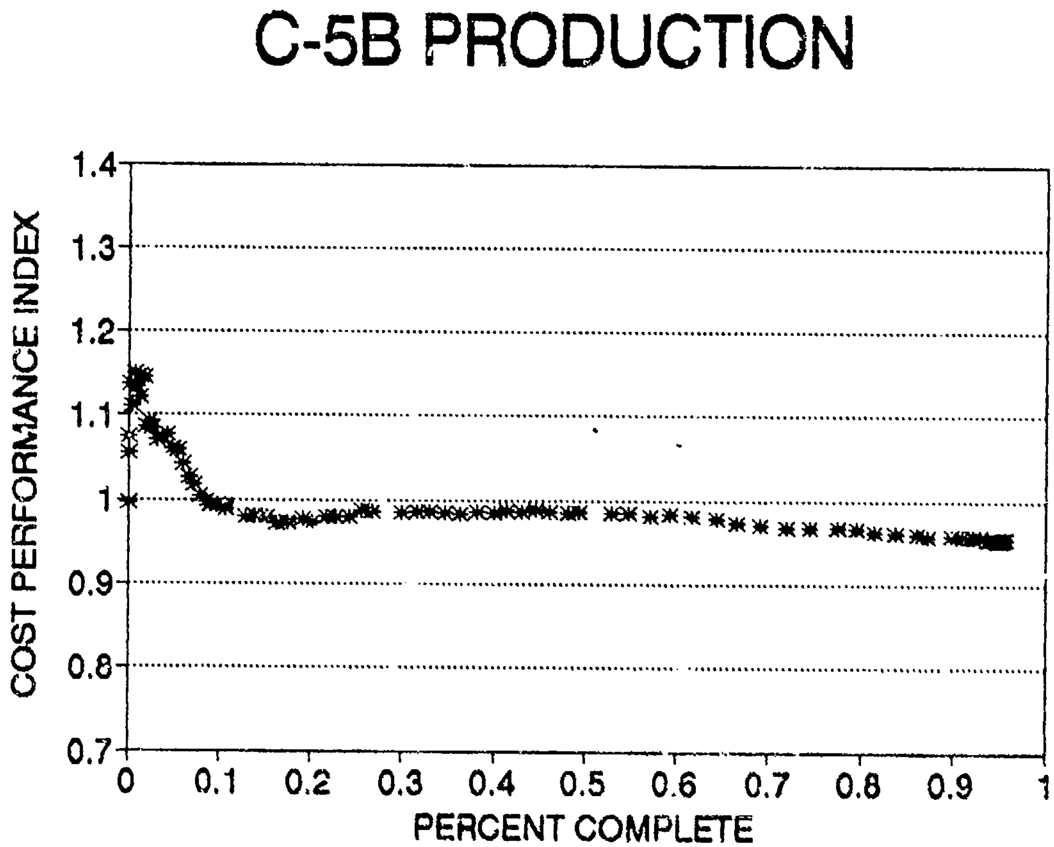

Figure 12. C-5B Production

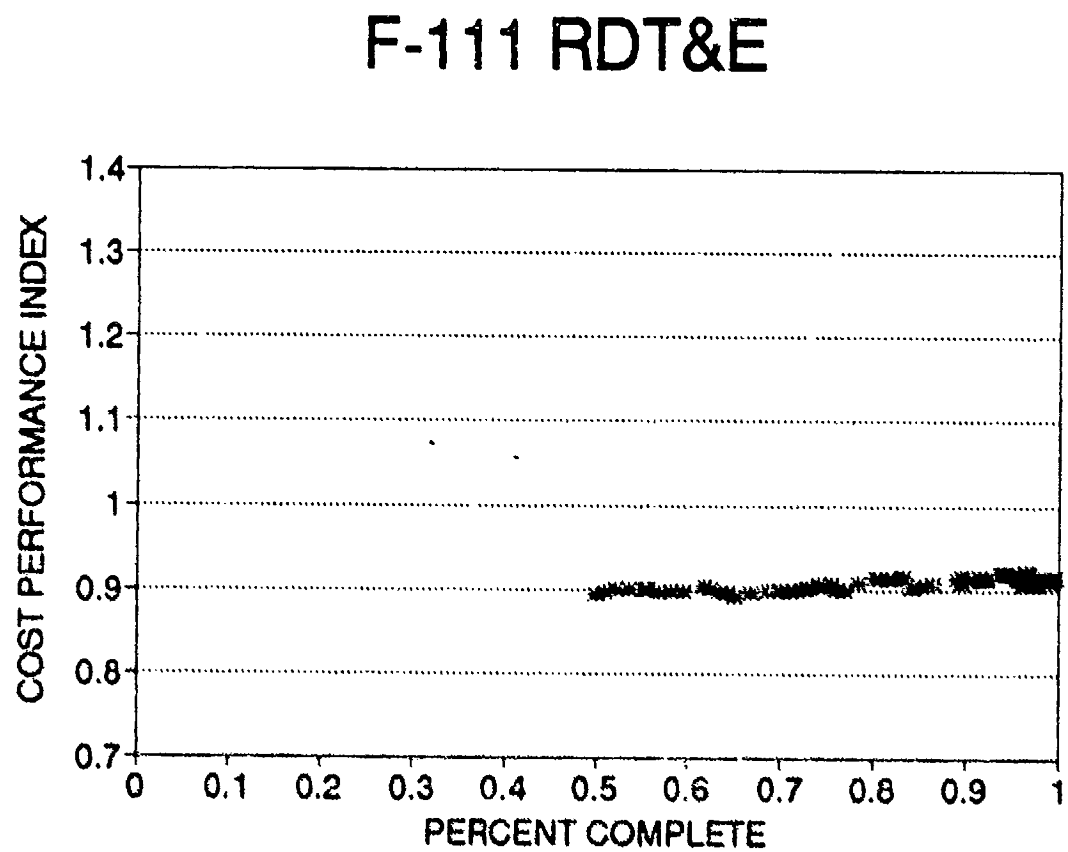

Figure 13. F-111 RDT&E

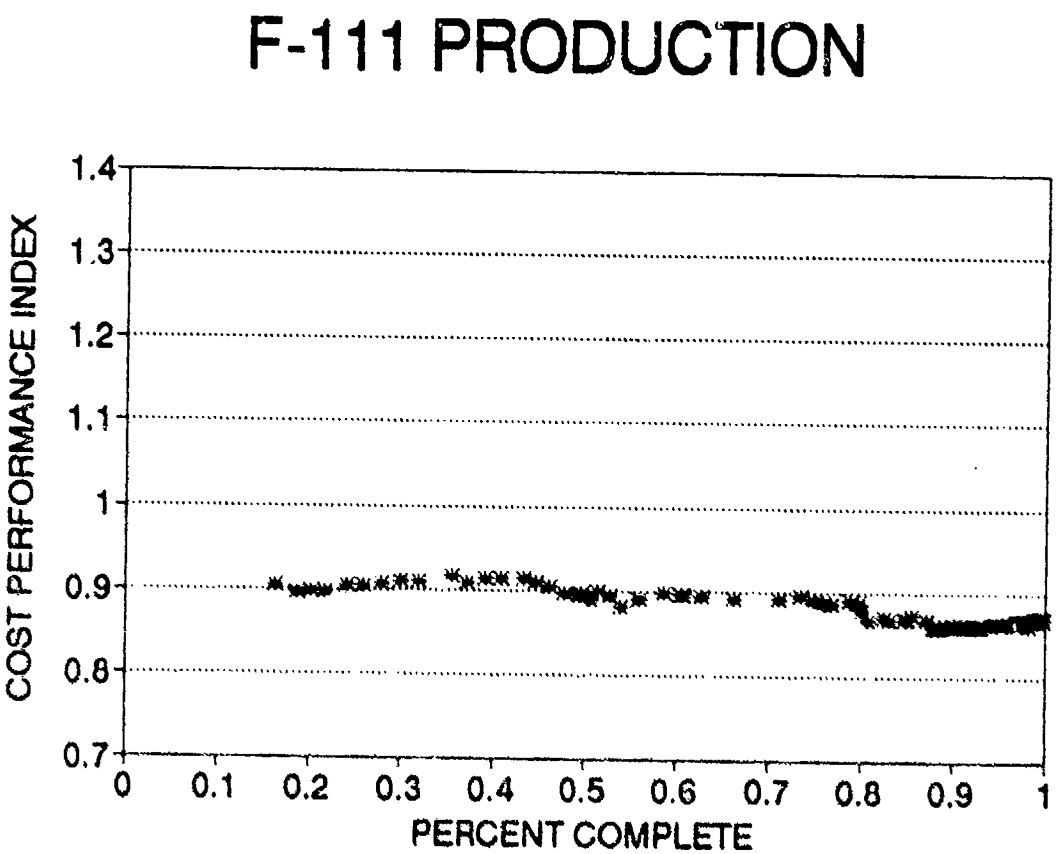

Figure 14. F-111 Production

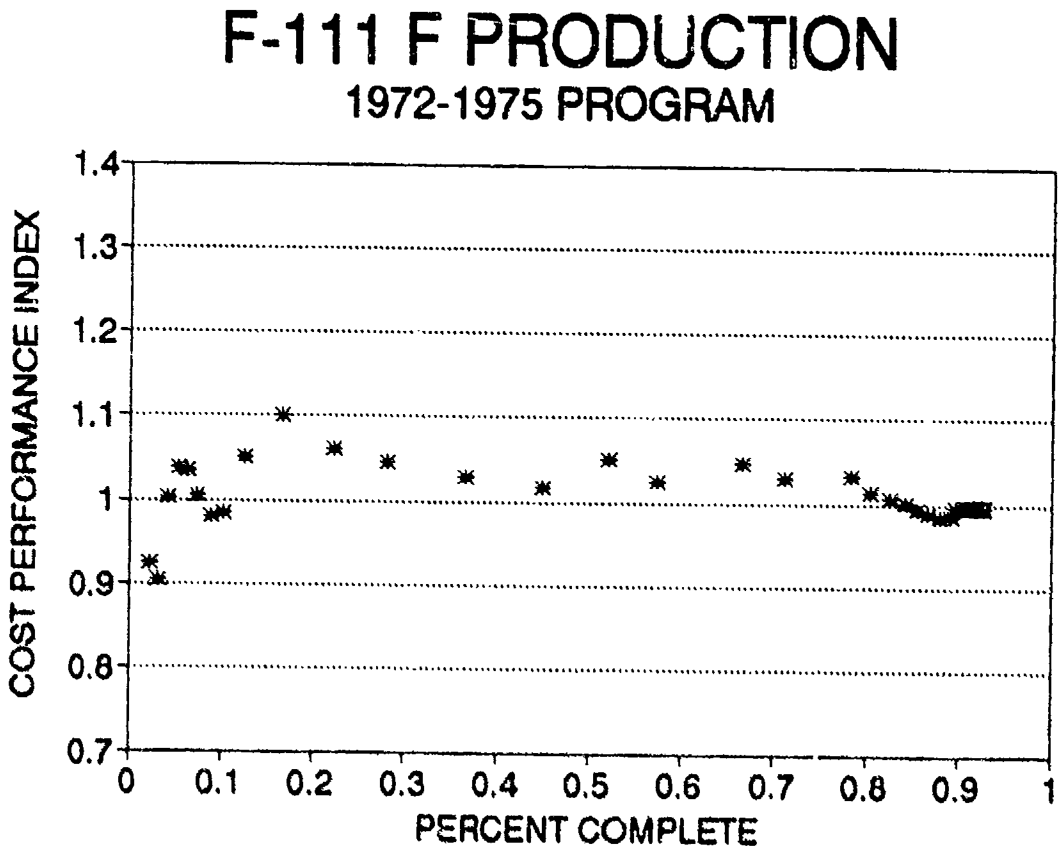

Figure 15. F-111 F Production 1972-1975 Program

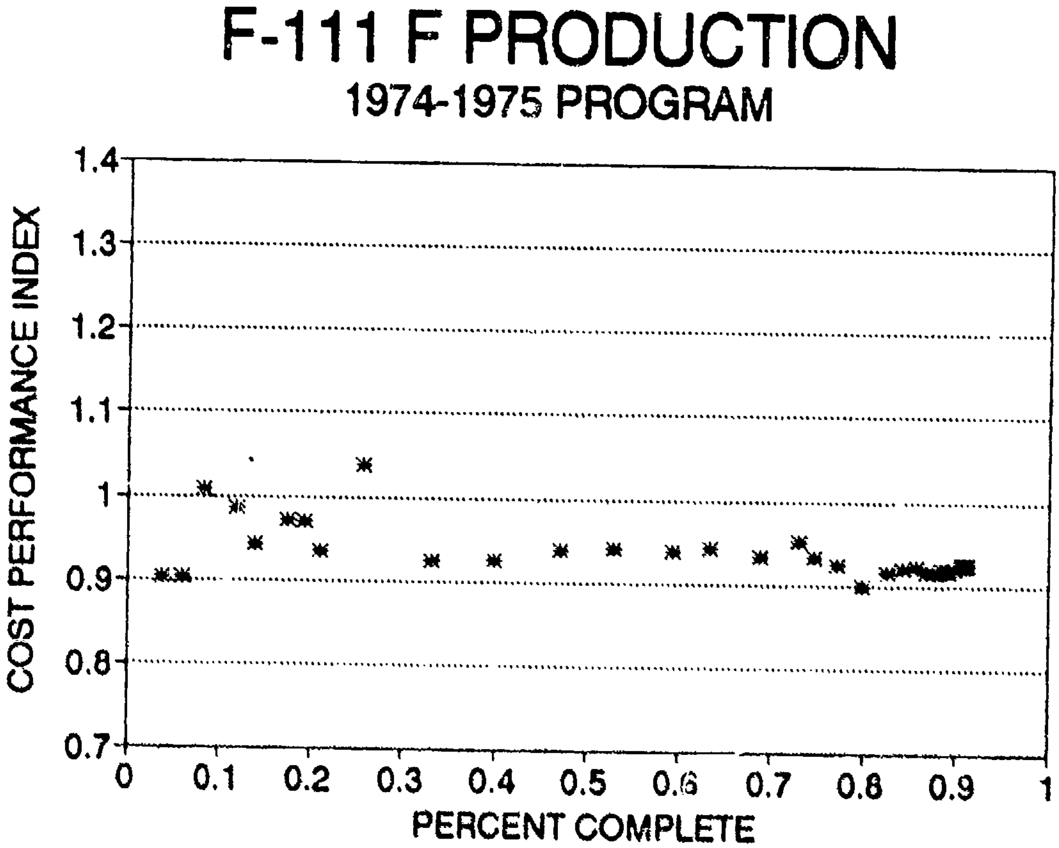

Figure 16. F-111 F Production 1974-1975 Program

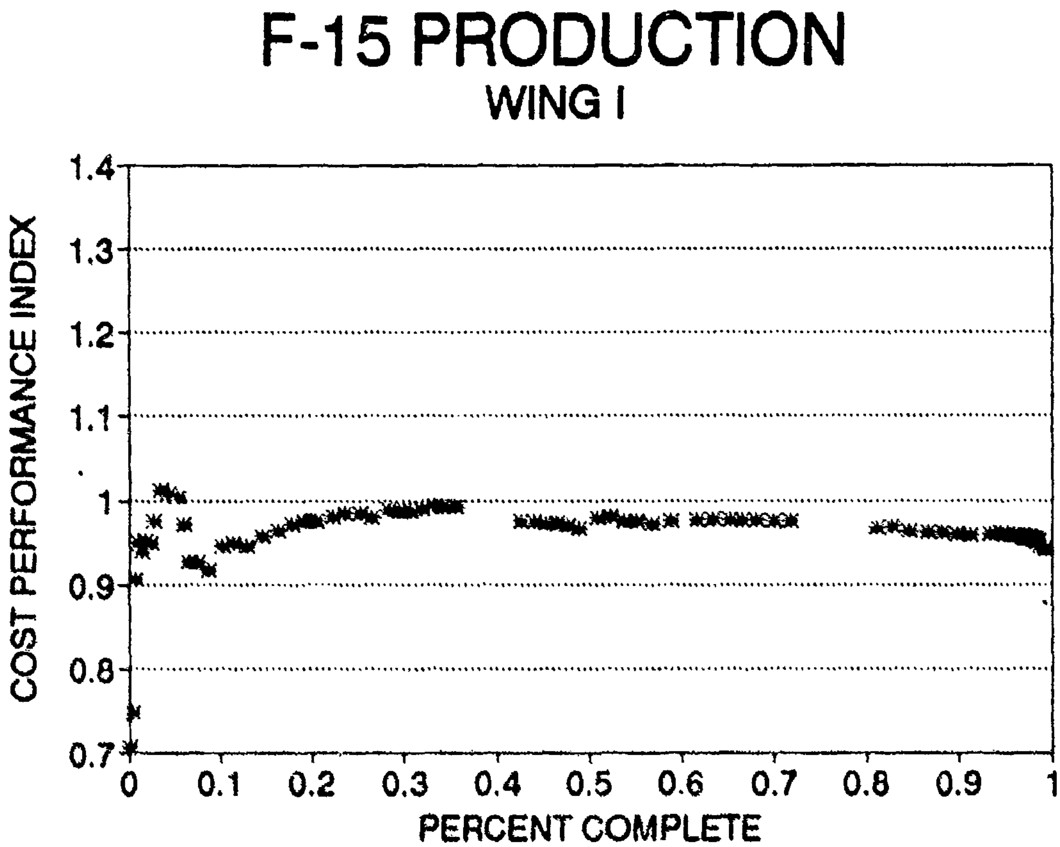

Figure 17. F-15 Production Thru Wing I

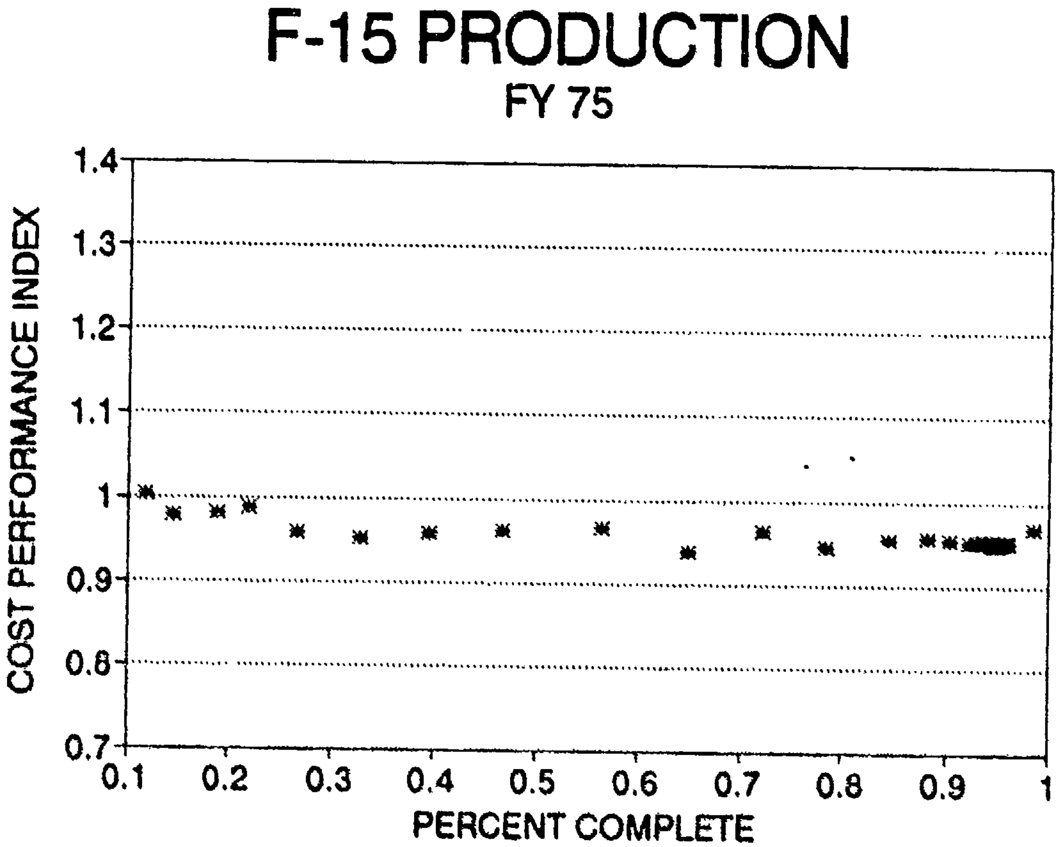

Figure 18. F-15 Production FY 75

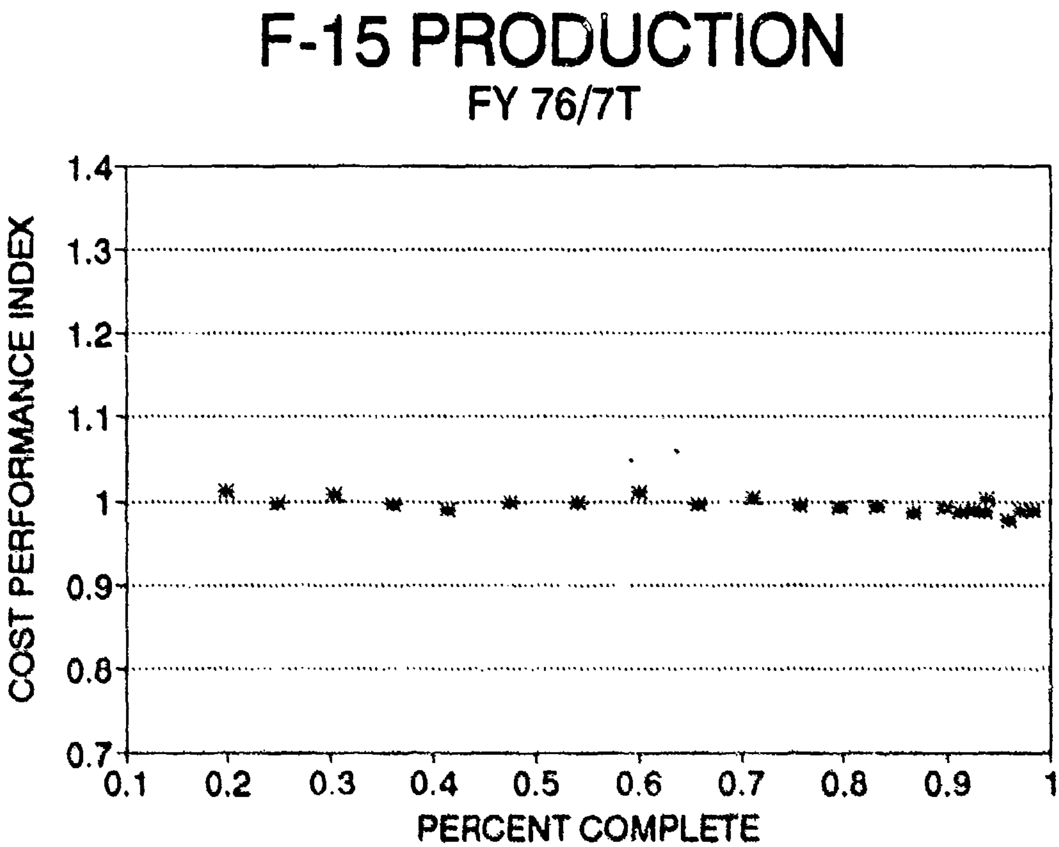

Figure 19. F-15 Production FY 76/7T

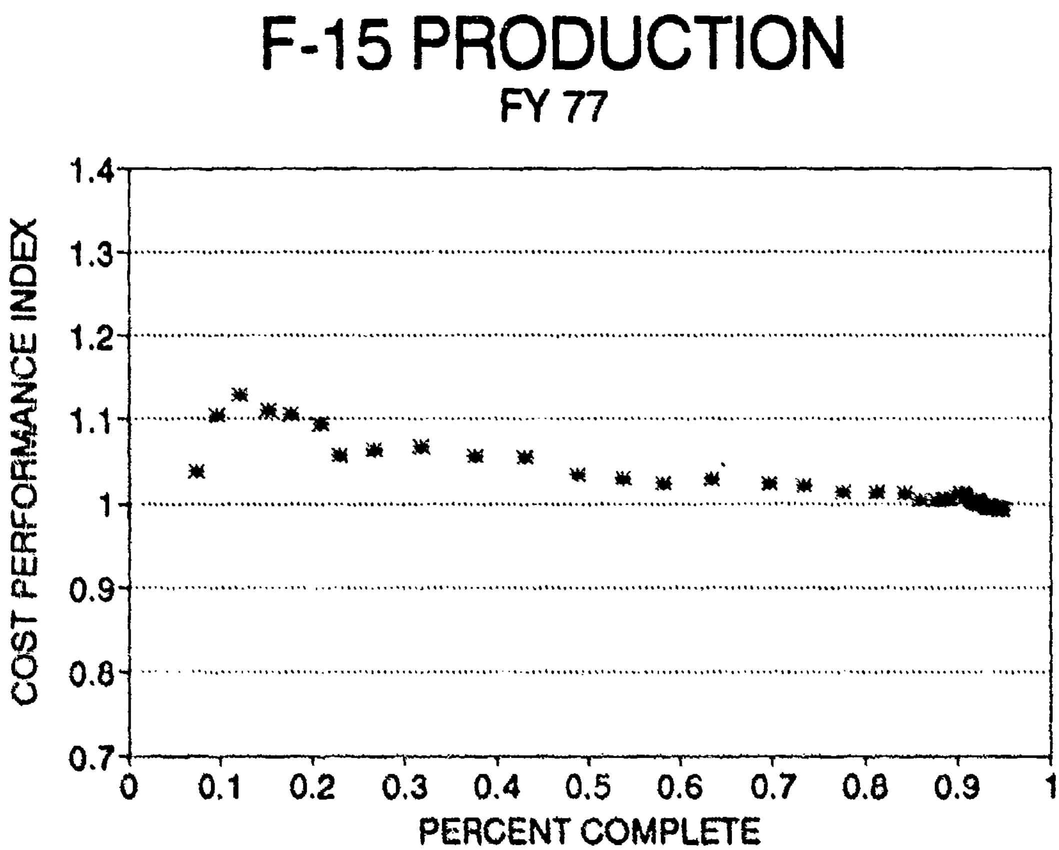

Figure 20. F-15 Production FY 77

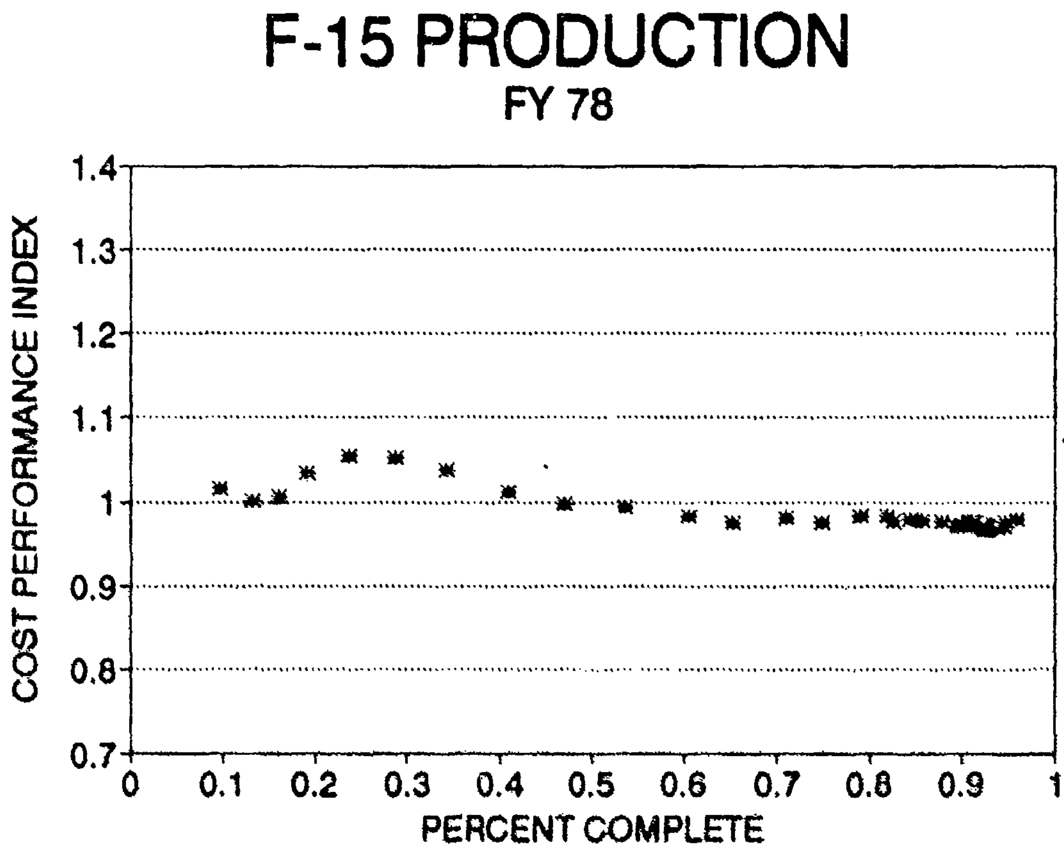

Figure 21. F-15 Production FY 78

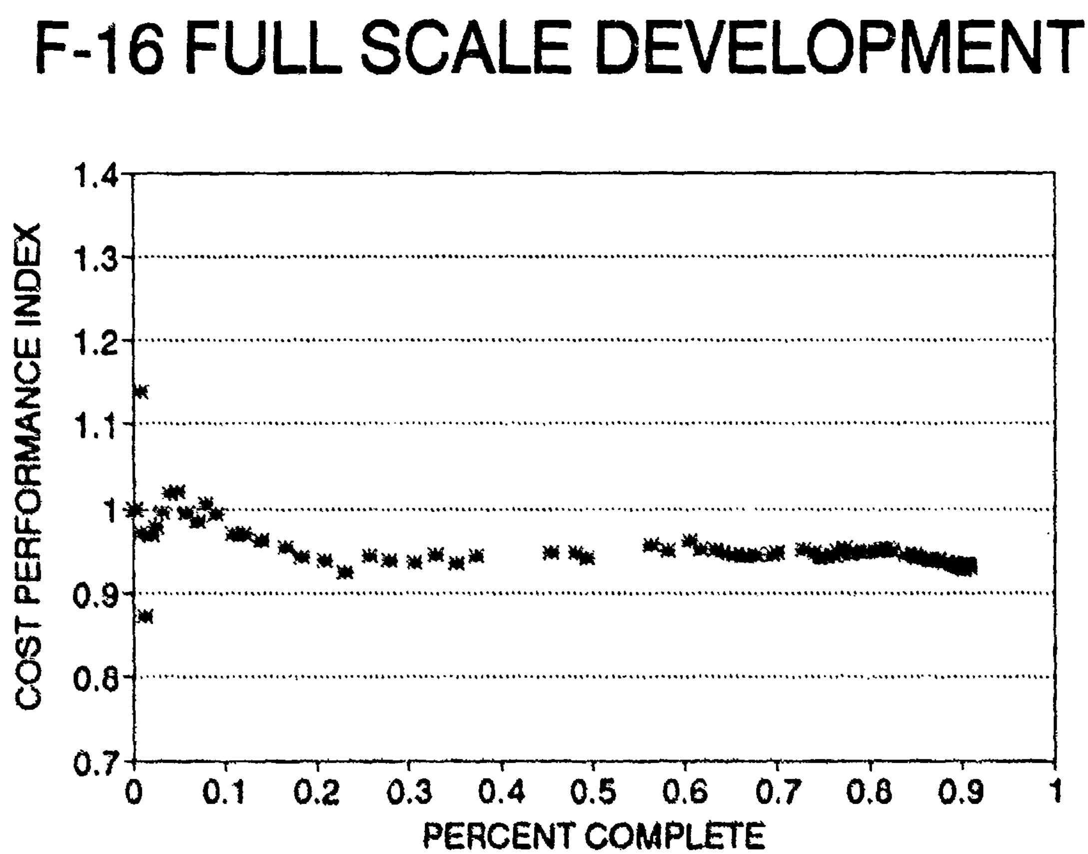

Figure 22. F-16 Full Scale Development

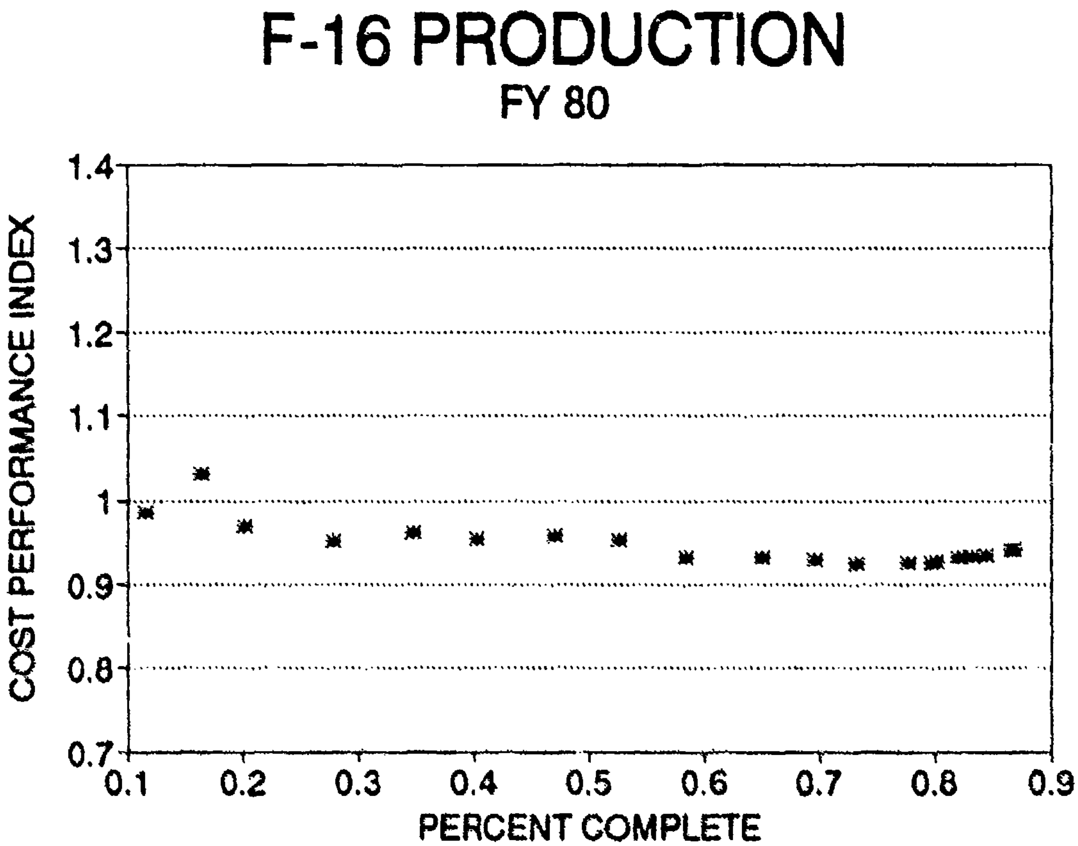

Figure 23. F-16 Production FY 80

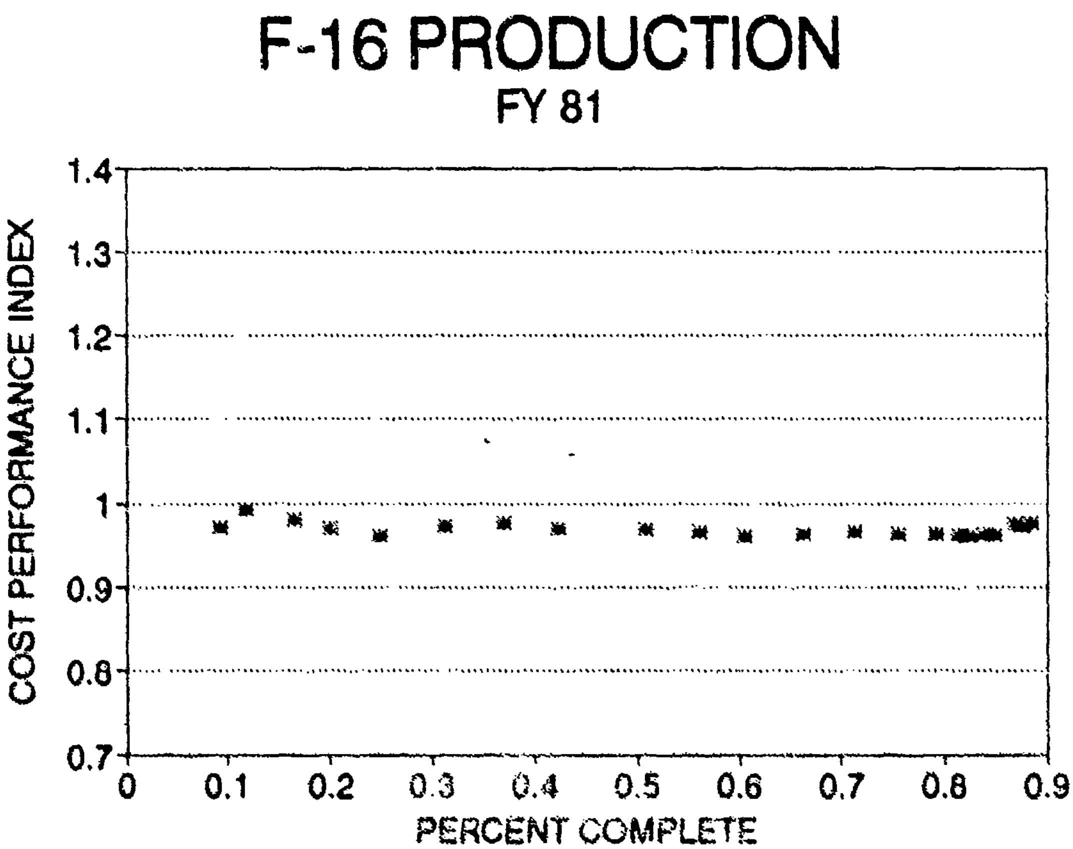

Figure 24. F-16 Production FY 81

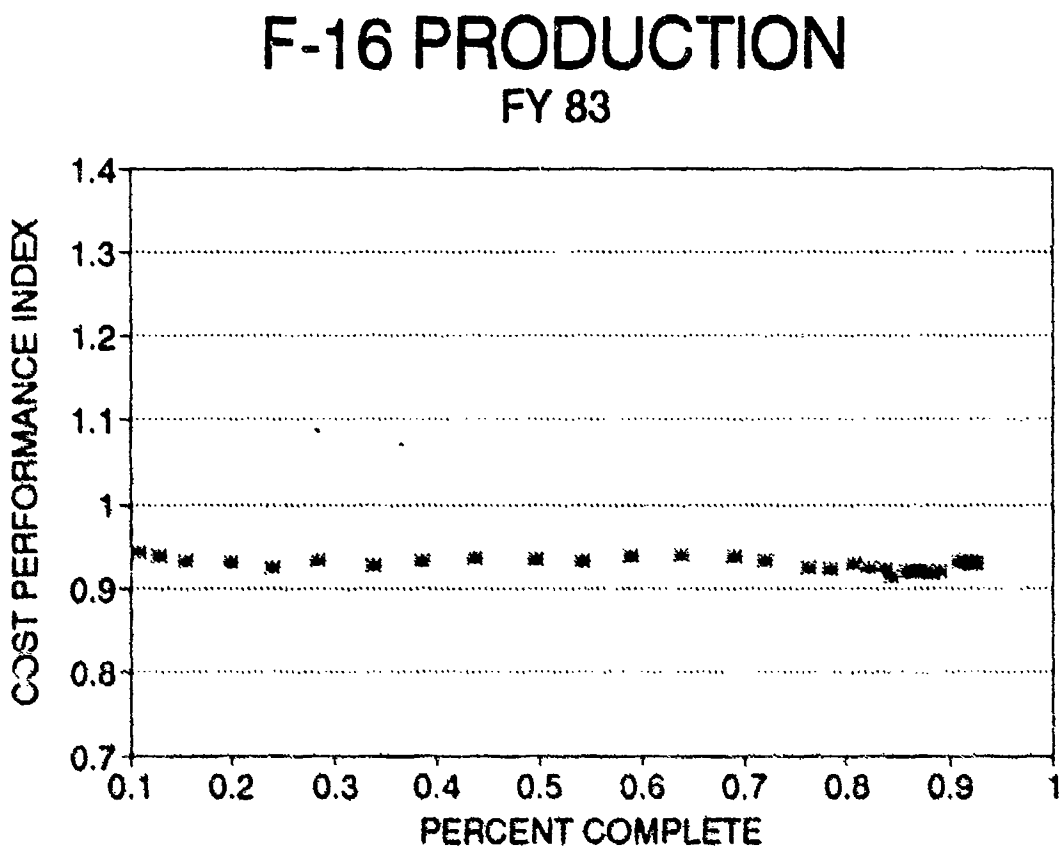

Figure 25. F-16 Production FY 83

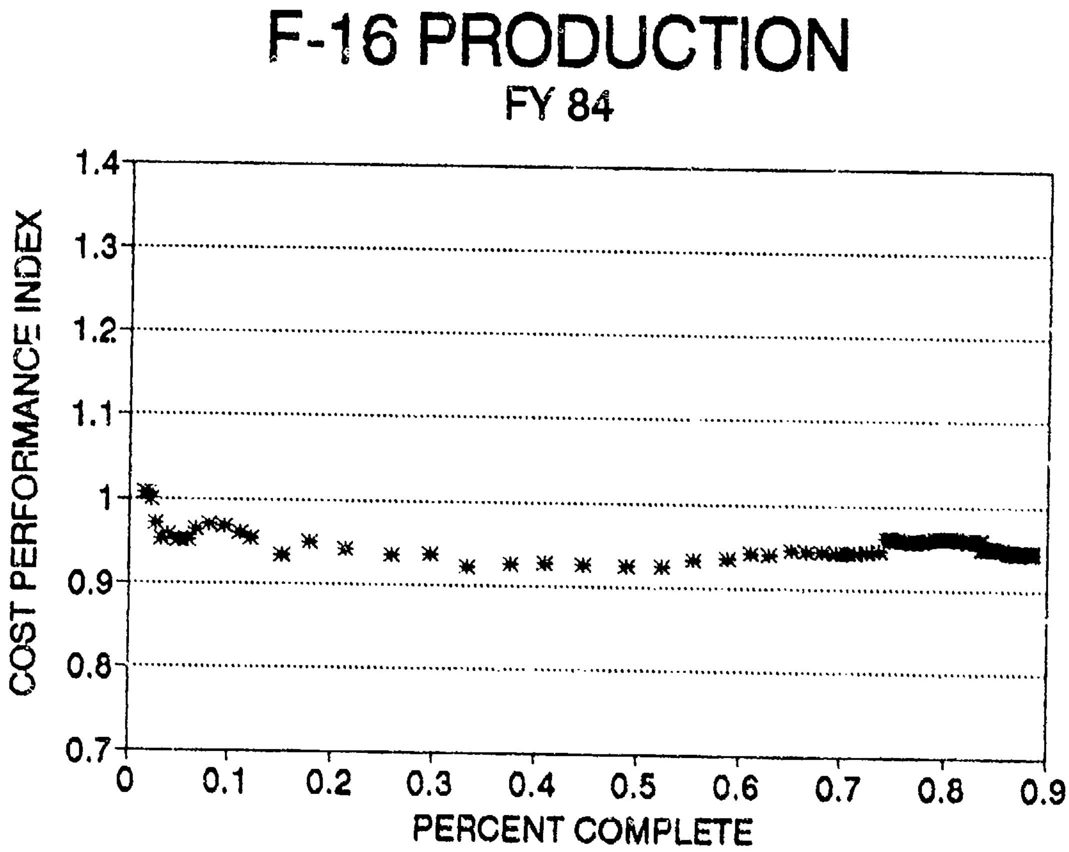

Figure 26. F-16 Production FY 84

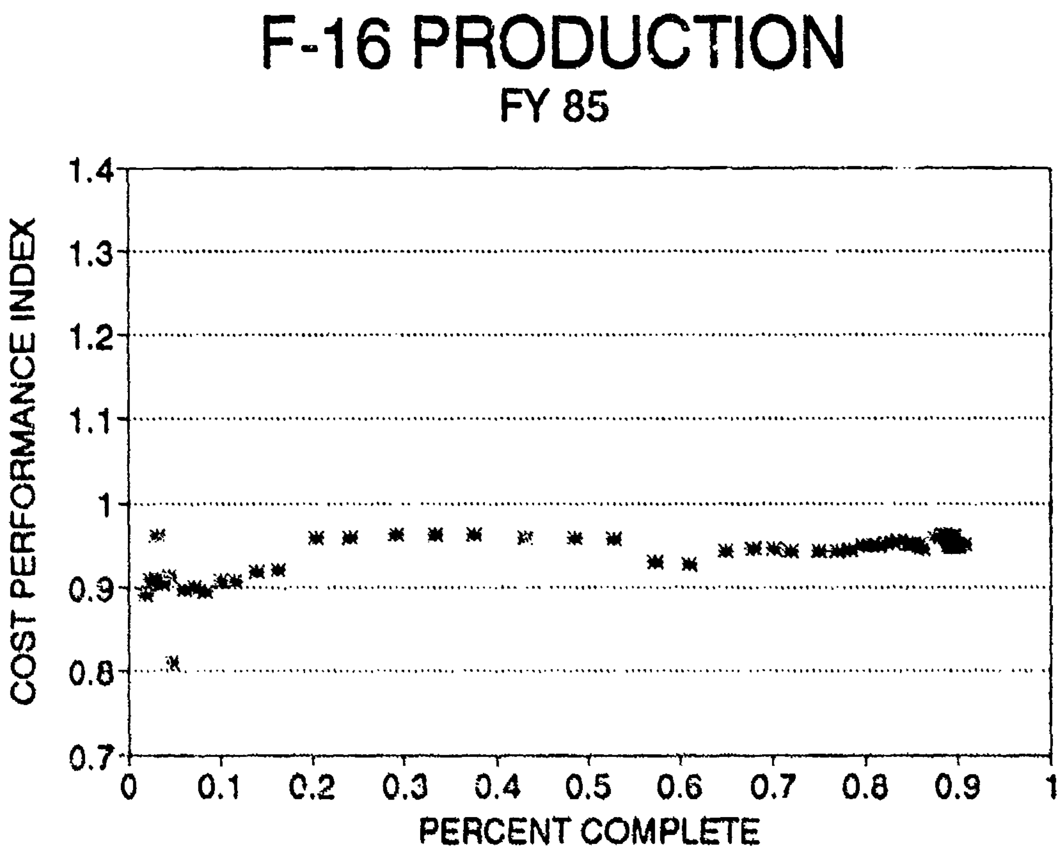

Figure 27. F-16 Production FY 85

Appendix C: Results of Range Method Calculations

TABLE 11

Calculations From 50 Percent Complete Beginning Point

Contract	Maximum	Minimum	Range
A-10 Program			
FSED	0.850	0.799	0.051
Option 1A	0.977	0.905	0.072
Option 2A	1.009	0.984	0.025
Option 3/4	1.109	1.042	0.067
Option 5A	1.140	1.059	0.082
Option 6A	1.042	0.968	0.074
Option 7A	0.980	0.939	0.040
B-1B Program			
Production	1.003	0.957	0.046
C-5A Program			
FSED	1.008	0.915	0.093
Production	1.038	0.998	0.040
C-5B Program			
Production	0.984	0.952	0.032
F-111 Program			
RDT&E	0.922	0.893	0.030
Production	0.898	0.858	0.039
F Model 1972 - 1975	1.052	0.984	0.068
F Model 1974 - 1975	0.952	0.899	0.053
F-15 Program			
Thru Wing I	0.981	0.941	0.040
FY 75	0.968	0.938	0.030
FY 76/7T	1.010	0.978	0.033
FY 77	1.030	0.992	0.038
FY 78	0.993	0.967	0.025
F-16 Program			
FSED	0.962	0.928	0.034
FY 80	0.953	0.925	0.029
FY 81	0.976	0.961	0.015
FY 83	0.939	0.913	0.026
FY 84	0.962	0.924	0.038
FY 85	0.962	0.927	0.035

TABLE 12

Calculations From 40 Percent Complete Beginning Point

Contract	Maximum	Minimum	Range
A-10 Program			
FSED	0.864	0.799	0.065
Option 1A	0.987	0.905	0.082
Option 2A	1.009	0.964	0.045
Option 3/4	1.109	1.042	0.067
Option 5A	1.140	1.059	0.082
Option 6A	1.042	0.952	0.090
Option 7A	0.980	0.939	0.040
B-1B Program			
Production	1.010	0.957	0.053
C-5A Program			
FSED	1.008	0.915	0.093
Production	1.038	0.930	0.108
C-5B Program			
Production	0.988	0.952	0.036
F-111 Program			
RDT&E	--	--	--
Production	0.913	0.858	0.054
F Model 1972 - 1975	1.052	0.984	0.068
F Model 1974 - 1975	0.952	0.899	0.053
F-15 Program			
Thru Wing I	0.981	0.941	0.040
FY 75	0.968	0.938	0.030
FY 76/7T	1.010	0.976	0.033
FY 77	1.055	0.992	0.063
FY 78	1.011	0.967	0.044
F-16 Program			
FSED	0.962	0.928	0.034
FY 80	0.957	0.925	0.033
FY 81	0.976	0.961	0.015
FY 83	0.939	0.913	0.026
FY 84	0.962	0.924	0.038
FY 85	0.962	0.927	0.035

TABLE 13

Calculations From 30 Percent Complete Beginning Point

Contract	Maximum	Minimum	Range
A-10 Program			
FSED	0.907	0.799	0.108
Option 1A	0.987	0.905	0.082
Option 2A	1.009	0.938	0.070
Option 3/4	1.109	1.041	0.068
Option 5A	1.140	1.059	0.082
Option 6A	1.042	0.920	0.123
Option 7A	0.980	0.939	0.040
B-1B Program			
Production	1.020	0.957	0.063
C-5A Program			
FSED	1.008	0.915	0.093
Production	1.038	0.930	0.108
C-5B Program			
Production	0.988	0.952	0.036
F-111 Program			
RDT&E	--	--	--
Production	0.916	0.858	0.058
F Model 1972 - 1975	1.052	0.984	0.068
F Model 1974 - 1975	0.952	0.899	0.053
F-15 Program			
Thru Wing I	0.994	0.941	0.053
FY 75	0.968	0.938	0.030
FY 76/7T	1.010	0.976	0.033
FY 77	1.068	0.992	0.077
FY 78	1.038	0.967	0.071
F-16 Program			
FSED	0.962	0.928	0.034
FY 80	0.963	0.925	0.039
FY 81	0.976	0.961	0.015
FY 83	0.939	0.913	0.026
FY 84	0.962	0.921	0.041
FY 85	0.962	0.927	0.035

TABLE 14

Calculations From 20 Percent Complete Beginning Point

Contract	Maximum	Minimum	Range
A-10 Program			
FSED	0.954	0.799	0.155
Option 1A	0.987	0.905	0.082
Option 2A	1.009	0.938	0.070
Option 3/4	1.109	1.016	0.093
Option 5A	1.142	1.059	0.084
Option 6A	1.042	0.879	0.163
Option 7A	0.980	0.936	0.044
B-1B Program			
Production	1.026	0.957	0.069
C-5A Program			
FSED	1.008	0.898	0.110
Production	1.038	0.855	0.153
C-5B Program			
Production	0.988	0.952	0.036
F-111 Program			
RDT&E	--	--	--
Production	0.916	0.858	0.058
F Model 1972 - 1975	1.101	0.984	0.117
F Model 1974 - 1975	1.037	0.899	0.138
F-15 Program			
Thru Wing I	0.994	0.941	0.053
FY 75	0.987	0.938	0.049
FY 76/7T	1.010	0.976	0.033
FY 77	1.094	0.992	0.102
FY 78	1.054	0.967	0.087
F-16 Program			
FSED	0.962	0.924	0.038
FY 80	0.971	0.925	0.046
FY 81	0.976	0.961	0.015
FY 83	0.939	0.913	0.026
FY 84	0.962	0.921	0.041
FY 85	0.963	0.927	0.036

TABLE 15

Calculations From 10 Percent Complete Beginning Point

Contract	Maximum	Minimum	Range
A-10 Program			
FSED	0.963	0.799	0.164
Option 1A	0.987	0.905	0.082
Option 2A	1.009	0.919	0.090
Option 3/4	1.109	0.983	0.126
Option 5A	1.265	1.059	0.206
Option 6A	1.042	0.879	0.163
Option 7A	1.017	0.912	0.105
B-1B Program			
Production	1.027	0.957	0.070
C-5A Program			
FSED	1.008	0.898	0.110
Production	1.038	0.855	0.153
C-5B Program			
Production	0.992	0.952	0.039
F-111 Program			
RDT&E	—	—	—
Production	0.916	0.858	0.058
F Model 1972 - 1975	1.101	0.984	0.117
F Model 1974 - 1975	1.037	0.899	0.138
F-15 Program			
Thru Wing I	0.994	0.941	0.053
FY 75	1.003	0.938	0.065
FY 76/7T	1.011	0.976	0.035
FY 77	1.129	0.992	0.138
FY 78	1.054	0.967	0.087
F-16 Program			
FSED	0.971	0.924	0.047
FY 80	1.031	0.925	0.107
FY 81	0.992	0.961	0.031
FY 83	0.943	0.913	0.030
FY 84	0.962	0.921	0.041
FY 85	0.963	0.907	0.056

TABLE 16

Calculations From 0 Percent Complete Beginning Point

Contract	Maximum	Minimum	Range
A-10 Program			
FSED	0.986	0.530	0.456
Option 1A	0.987	0.639	0.348
Option 2A	1.009	0.901	0.108
Option 3/4	1.109	0.833	0.276
Option 5A	1.318	1.015	0.303
Option 6A	1.042	0.323	0.719
Option 7A	1.038	0.814	0.224
B-1B Program			
Production	1.076	0.957	0.119
C-5A Program			
FSED	--	--	--
Production	1.038	0.703	0.334
C-5B Program			
Production	1.152	0.952	0.199
F-111 Program			
RDT&E	--	--	--
Production	--	--	--
F Model 1972 - 1975	1.101	0.905	0.196
F Model 1974 - 1975	1.037	0.899	0.138
F-15 Program			
Thru Wing I	1.012	0.706	0.305
FY 75	--	--	--
FY 76/7T	--	--	--
FY 77	1.129	0.992	0.138
FY 78	1.054	0.967	0.087
F-16 Program			
FSED	1.140	0.873	0.267
FY 80	--	--	--
FY 81	0.992	0.961	0.031
FY 83	--	--	--
FY 84	1.006	0.921	0.086
FY 85	0.963	0.811	0.152

Appendix D. Results of Interval Method Calculations

TABLE 17

Calculations From 50 Percent Complete Beginning Point

Contract	+ 10%	- 10%	+ 7.5%	- 7.5%	+ 5%	- 5%
A-10 Program						
FSED	0.934	0.764	0.912	0.785	0.891	0.806
Option 1A	1.074	0.879	1.050	0.904	1.026	0.928
Option 2A	1.086	0.888	1.061	0.913	1.036	0.937
Option 3/4	1.202	0.983	1.175	1.011	1.147	1.038
Option 5A	1.184	0.968	1.157	0.995	1.130	1.022
Option 6A	1.117	0.914	1.091	0.939	1.066	0.964
Option 7A	1.078	0.882	1.053	0.906	1.029	0.931
B-1B Program						
Production	1.103	0.903	1.078	0.928	1.053	0.953
C-5A Program						
FSED	1.097	0.898	1.072	0.922	1.047	0.947
Production	1.098	0.898	1.073	0.923	1.048	0.948
C-5B Program						
Production	1.083	0.886	1.058	0.[illegible]10	1.033	0.935
F-111 Program						
RDT&E	0.983	0.804	0.961	0.827	0.938	0.849
Production	0.990	0.810	0.967	0.832	0.945	0.855
F Model 1972 - 1975	1.157	0.947	1.131	0.973	1.105	0.999
F Model 1974 - 1975	1.035	0.847	1.012	0.871	0.988	0.894
F-15 Program						
Thru Wing I	1.078	0.882	1.053	0.906	1.029	0.931
FY 75	1.063	0.870	1.039	0.894	1.015	0.918
FY 76/7T	1.100	0.900	1.075	0.925	1.050	0.950
FY 77	1.133	0.927	1.107	0.952	1.081	0.978
FY 78	1.092	0.893	1.067	0.918	1.042	0.943
F-16 Program						
FSED	1.052	0.860	1.028	0.884	1.004	0.908
FY 80	1.049	0.858	1.025	0.882	1.001	0.906
FY 81	1.065	0.872	1.041	0.896	1.017	0.920
FY 83	1.026	0.839	1.002	0.862	0.979	0.886
FY 84	1.016	0.832	0.993	0.855	0.970	0.878
FY 35	1.053	0.861	1.029	0.885	1.005	0.909

TABLE 18

Calculations From 40 Percent Complete Beginning Point

Contract	+ 10%	- 10%	+ 7.5%	- 7.5%	+ 5%	- 5%
A-10 Program						
FSED	0.950	0.777	0.929	0.799	0.907	0.821
Option 1A	1.063	0.870	1.039	0.894	1.015	0.918
Option 2A	1.060	0.867	1.036	0.891	1.012	0.915
Option 3/4	1.151	0.942	1.125	0.968	1.099	0.994
Option 5A	1.219	0.998	1.192	1.025	1.164	1.053
Option 6A	1.048	0.857	1.024	0.881	1.000	0.905
Option 7A	1.077	0.882	1.053	0.906	1.028	0.930
B-1B Program						
Production	1.111	0.909	1.086	0.934	1.061	0.960
C-5A Program						
FSED	1.085	0.888	1.061	0.913	1.036	0.937
Production	1.035	0.847	1.011	0.870	0.988	0.894
C-5B Program						
Production	1.083	0.886	1.058	0.911	1.034	0.935
F-111 Program						
RDT&E	--	--	--	--	--	--
Production	1.004	0.822	0.981	0.845	0.959	0.867
F Model 1972 - 1975	1.120	0.917	1.095	0.942	1.069	0.968
F Model 1974 - 1975	1.031	0.844	1.008	0.867	0.984	0.891
F-15 Program						
Thru Wing I	1.073	0.878	1.048	0.902	1.024	0.927
FY 75	1.059	0.867	1.035	0.891	1.011	0.915
FY 76/7T	1.090	0.891	1.065	0.916	1.040	0.941
FY 77	1.161	0.950	1.134	0.976	1.108	1.002
FY 78	1.112	0.910	1.087	0.935	1.062	0.960
F-16 Program						
FSED	1.042	0.852	1.018	0.876	0.994	0.900
FY 80	1.050	0.859	1.026	0.883	1.002	0.907
FY 81	1.068	0.874	1.044	0.898	1.020	0.922
FY 83	1.030	0.843	1.007	0.867	0.984	0.890
FY 84	1.020	0.835	0.997	0.858	0.974	0.881
FY 85	1.055	0.863	1.031	0.887	1.007	0.911

TABLE 19

Calculations From 30 Percent Complete Beginning Point

Contract	+ 10%	- 10%	+ 7.5%	- 7.5%	+ 5%	- 5%
A-10 Program						
FSED	0.997	0.816	0.975	0.839	0.952	0.861
Option 1A	1.078	0.882	1.054	0.907	1.029	0.931
Option 2A	1.032	0.845	1.009	0.868	0.985	0.891
Option 3/4	1.145	0.937	1.119	0.963	1.093	0.989
Option 5A	1.238	1.013	1.210	1.041	1.182	1.070
Option 6A	1.012	0.828	0.989	0.851	0.966	0.874
Option 7A	1.044	0.854	1.020	0.878	0.997	0.902
B-1B Program						
Production	1.122	0.918	1.096	0.943	1.071	0.969
C-5A Program						
FSED	1.096	0.897	1.071	0.922	1.046	0.947
Production	1.056	0.864	1.032	0.888	1.008	0.912
C-5B Program						
Production	1.082	0.885	1.058	0.910	1.033	0.935
F-111 Program						
RDT&E	--	--	--	--	--	--
Production	1.002	0.820	0.979	0.842	0.956	0.865
F Model 1972 - 1975	1.131	0.925	1.105	0.951	1.080	0.977
F Model 1974 - 1975	1.017	0.832	0.994	0.856	0.971	0.879
F-15 Program						
Thru Wing I	1.085	0.888	1.061	0.913	1.036	0.937
FY 75	1.048	0.857	1.024	0.881	1.000	0.905
FY 76/7T	1.109	0.908	1.084	0.933	1.059	0.958
FY 77	1.175	0.961	1.148	0.988	1.122	1.015
FY 78	1.142	0.935	1.116	0.961	1.090	0.987
F-16 Program						
FSED	1.030	0.843	1.007	0.867	0.984	0.890
FY 80	1.059	0.867	1.035	0.891	1.011	0.915
FY 81	1.070	0.875	1.046	0.900	1.021	0.924
FY 83	1.020	0.835	0.997	0.858	0.974	0.881
FY 84	1.013	0.829	0.990	0.852	0.967	0.875
FY 85	1.058	0.866	1.034	0.890	1.010	0.914

TABLE 20

Calculations From 20 Percent Complete Beginning Point

Contract	+ 10%	- 10%	+ 7.5%	- 7.5%	+ 5%	- 5%
A-10 Program						
FSED	1.050	0.859	1.026	0.883	1.002	0.906
Option 1A	1.036	0.848	1.012	0.871	0.989	0.895
Option 2A	1.034	0.846	1.011	0.870	0.987	0.893
Option 3/4	1.131	0.925	1.105	0.951	1.080	0.977
Option 5A	1.219	0.997	1.191	1.025	1.164	1.053
Option 6A	1.132	0.927	1.107	0.952	1.081	0.978
Option 7A	1.056	0.864	1.032	0.888	1.008	0.912
B-1B Program						
Production	1.128	0.923	1.103	0.949	1.077	0.974
C-5A Program						
FSED	1.021	0.836	0.998	0.859	0.975	0.882
Production	0.973	0.796	0.951	0.818	0.929	0.841
C-5B Program						
Production	1.071	0.876	1.047	0.901	1.022	0.925
F-111 Program						
RDT&E	--	--	--	--	--	--
Production	0.989	0.809	0.966	0.832	0.944	0.854
F Model 1972 - 1975	1.168	0.955	1.141	0.982	1.115	1.009
F Model 1974 - 1975	1.029	0.842	1.006	0.866	0.983	0.889
F-15 Program						
Thru Wing I	1.072	0.877	1.048	0.902	1.024	0.926
FY 75	1.086	0.888	1.061	0.913	1.036	0.938
FY 76/7T	1.097	0.898	1.072	0.923	1.047	0.948
FY 77	1.203	0.984	1.176	1.012	1.148	1.039
FY 78	1.160	0.949	1.133	0.975	1.107	1.001
F-16 Program						
FSED	1.031	0.844	1.008	0.867	0.984	0.891
FY 80	1.068	0.873	1.043	0.898	1.019	0.922
FY 81	1.057	0.865	1.033	0.889	1.009	0.913
FY 83	1.016	0.832	0.993	0.855	0.970	0.878
FY 84	1.035	0.847	1.011	0.870	0.988	0.894
FY 85	1.055	0.863	1.031	0.887	1.007	0.911

TABLE 21

Calculations From 10 Percent Complete Beginning Point

Contract	+ 10%	- 10%	+ 7.5%	- 7.5%	+ 5%	- 5%
A-10 Program						
FSED	1.059	0.867	1.035	0.891	1.011	0.915
Option 1A	1.073	0.878	1.048	0.902	1.024	0.926
Option 2A	1.046	0.856	1.022	0.880	0.998	0.903
Option 3/4	1.081	0.884	1.056	0.909	1.032	0.933
Option 5A	1.391	1.138	1.359	1.170	1.328	1.201
Option 6A	1.106	0.905	1.081	0.930	1.056	0.955
Option 7A	1.119	0.916	1.094	0.941	1.068	0.967
B-18 Program						
Production	1.119	0.916	1.094	0.941	1.068	0.967
C-5A Program						
FSED	1.084	0.887	1.060	0.912	1.035	0.937
Production	1.094	0.895	1.069	0.920	1.044	0.945
C-5B Program						
Production	1.091	0.892	1.066	0.917	1.041	0.942
F-111 Program						
RDT&E	--	--	--	--	--	--
Production	0.995	0.814	0.972	0.836	0.949	0.859
F Model 1972 - 1975	1.083	0.866	1.068	0.911	1.034	0.935
F Model 1974 - 1975	1.084	0.887	1.059	0.912	1.035	0.936
F-15 Program						
Thru Wing I	1.041	0.851	1.017	0.875	0.933	0.899
FY 75	1.103	0.903	1.078	0.928	1.053	0.953
FY 76/7T	1.112	0.910	1.087	0.935	1.062	0.960
FY 77	1.242	1.016	1.214	1.045	1.186	1.073
FY 78	1.101	0.901	1.076	0.926	1.051	0.951
F-16 Program						
FSED	1.068	0.874	1.044	0.898	1.019	0.922
FY 80	1.084	0.887	1.059	0.911	1.034	0.936
FY 81	1.091	0.893	1.067	0.918	1.042	0.943
FY 83	1.038	0.849	1.014	0.873	0.991	0.896
FY 84	1.056	0.864	1.032	0.888	1.008	0.912
FY 75	0.998	0.817	0.975	0.839	0.953	0.862

TABLE 22

Calculations From 0 Percent Complete Beginning Point

Contract	+ 10%	- 10%	+ 7.5%	- 7.5%	+ 5%	- 5%
A-10 Program						
FSED	0.583	C 477	0.570	0.490	0.556	0.503
Option 1A	0.703	0.575	0.687	0.591	0.671	0.607
Option 2A	1.063	0.870	1.039	0.894	1.015	0.918
Option 3/4	0.916	0.749	0.895	0.770	0.874	0.791
Option 5A	1.117	0.914	1.092	0.939	1.066	0.965
Option 6A	0.634	0.519	0.620	0.533	0.605	0.548
Option 7A	0.895	0.732	0.875	0.753	0.854	0.773
B-1B Program						
Production	1.109	0.907	1.084	0.932	1.058	0.958
C-5A Program						
FSED	--	--	--	--	--	--
Production	0.985	0.806	0.962	0.828	0.940	0.850
C-5B Program						
Production	1.096	0.897	1.071	0.922	1.047	0.947
F-111 Program						
RDT&E	--	--	--	--	--	--
Production	--	--	--	--	--	--
F Model 1972 - 1975	1.017	0.832	0.994	0.855	0.971	0.878
F Model 1974 - 1975	0.993	0.812	0.970	0.835	0.947	0.857
F-15 Program						
Thru Wing I	0.777	0.636	0.759	0.653	0.741	0.671
FY 75	--	--	--	--	--	--
FY 76/7T	--	--	--	--	--	--
FY 77	1.142	0.934	1.116	0.960	1.090	0.986
FY 78	1.118	0.914	1.092	0.940	1.067	0.965
F-16 Program						
FSED	1.100	0.900	1.075	0.925	1.050	0.950
FY 80	--	--	--	--	--	--
FY 81	1.068	0.874	1.044	0.898	1.020	0.923
FY 83	--	--	--	--	--	--
FY 84	1.107	0.906	1.082	0.931	1.057	0.956
FY 85	0.980	0.802	0.957	0.824	0.935	0.846

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13. ABSTRACT *(Maximum 200 words)*
This study examines the stability of the Cost Performance Index (CPI). The CPI is and indicator of the cost performance efficiency achieved on a contract and is used to analyze cost performance on defense contracts. It has long been asserted that the index does not change by more than 10 percent after a contract is 50 percent complete, but an exhaustive literature search did not locate any empirical work that supports this assertion. Knowing that the CPI is stable is important because it indicates that a contractor has a healthy management system, it increases the reliability placed in the contractor's planning process, it gives confidence in our Estimate at Completion computations, and if a contractor is overrunning his budget, it gives confidence when declaring the contractor in trouble.

After defining CPI stability two methods to test for stability were developed. The two methods chosen were: first, to measure the range of the CPIs that occurred at greater than 50 percent complete and second, to calculate a percentage interval and verify that the CPI falls within the bounds of this interval. The results of both methods show that the CPI is stable after a contract is 50 percent complete.
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